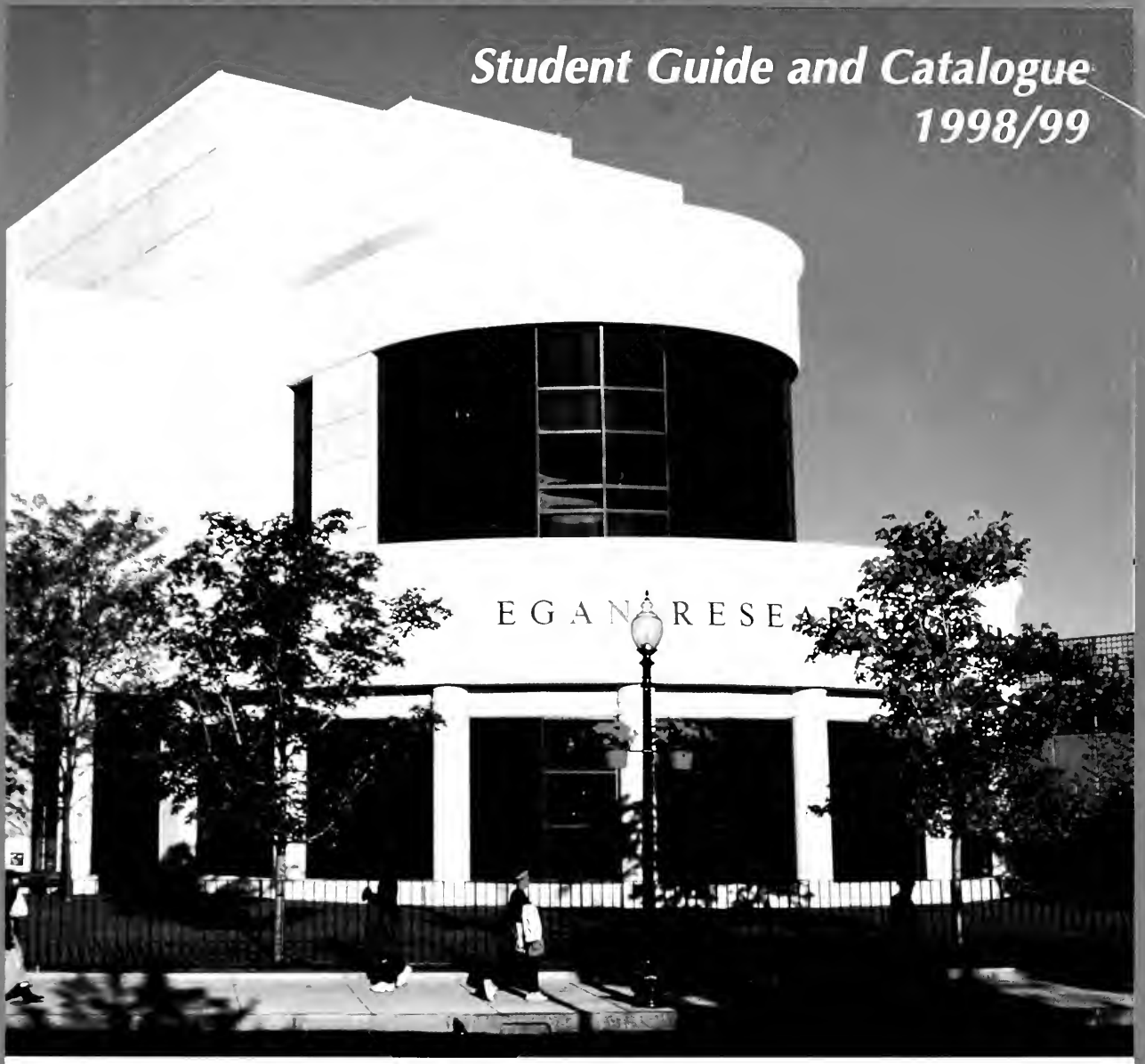
GRADUATE SCHOOL OF ENGINEERING

Student Guide and Catalogue 1998/99



Chemical Engineering
Civil and Environmental Engineering
Computer Systems Engineering
Electrical and Computer Engineering
Information Systems
Mechanical, Industrial, and Manufacturing Engineering
Operations Research

Northeastern University

Web address: http://www.coe.neu.edu

Graduate School of Engineering

Student Guide and Catalogue 1998/99

Northeastern University

Boston Massachusetts

NORTHEASTERN UNIVERSITY
GRADUATE SCHOOL OF ENGINEERING

This Student Guide and Catalog of the Graduate School of Engineering at Northeastern University has been developed solely for the convenience of our graduate students to help plan their program of study.

The Graduate School of Engineering is located in room 130 of the Snell Engineering Center on the Boston Campus. During the fall, winter and spring quarters it is staffed from 8:30 AM to 4:30 PM, Monday through Friday. There are office hours in the evenings during the academic year from 5:00 PM to 8:00PM on Mondays in Boston and at the suburban campus in Burlington from 5:00 PM to 8:00 PM on Thursdays. During the summer, the Graduate School office is staffed from 8:00 AM to 5:00 PM, Monday through Friday. All administrative matters should be referred to the Graduate School office. The staff consists of:

Dr. Yaman Yener	*Director*
Stephen L. Gibson	*Associate Director*
Jennifer A. Black	*Assistant Director*
Marlys D. Vaughan	*Administrative Assistant*
Hattie M. Williams	*Staff Assistant*

You may reach the Graduate School of Engineering by calling (617) 373-2711.

Dr. Yaman Yener
Associate Dean of Engineering
for Research and Graduate Studies

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The University

The city of Boston has played a pioneering role in American education. Today it has one of the largest and most diverse student populations in the country. Located at the center of Boston's thriving educational and cultural life, Northeastern University is dedicated to excellence in research and scholarship and is committed to responding to the educational needs of individuals and the community. Since its beginning Northeastern has pioneered a wide range of educational programs and services for students of all ages.

Northeastern University's roots lie in the Evening Institute for Young Men founded in Boston in 1898. Classes in law were offered at a reasonable cost during the evening for those who worked during the day. The first evening law school in Boston quickly expanded to include other disciplines and added an innovative daytime program which alternated classroom study with work experience. By the time Northeastern was incorporated as a university in 1922, the school had committed itself to "cooperative education by day, adult education in the evening."

Almost a century after its founding, Northeastern is a comprehensive university with eight undergraduate colleges, eight graduate and professional schools, five suburban campuses, and an extensive research division. A private nonsectarian institution of higher learning chartered and authorized to grant degrees by the Commonwealth of Massachusetts, the University is governed by a Board of Trustees elected by and from the Northeastern University Corporation, which is composed of approximately 200 distinguished academic and professional leaders from around the country.

Northeastern University has developed a reputation as a world leader in cooperative education. The Cooperative Plan of Education, initiated by the College of Engineering in 1909 and subsequently adopted by the other colleges of the University, enables students to alternate periods of paid professional work and study. This educational method offers students an opportunity to gain valuable practical experience as an integral part of their education. Begun at the full-time undergraduate level, the cooperative education philosophy has been extended to the graduate level in engineering, business administration, law, professional accounting, and criminal justice.

The University's eight graduate and professional schools including Arts and Sciences, Bouvé College of Pharmacy and Health Sciences, Business Administration, Computer Science, Criminal Justice, Engineering, Law, and Nursing offer programs leading to Master's and Doctor's degrees in a wide array of liberal arts and professional courses of study. In the field of adult education, the University offers full- and part-time graduate degree programs that are specifically designed to meet the needs and interests of adults who wish to further their education and meet their professional and career aspirations.

As a graduate student at Northeastern University, you will discover that part of the advantage of studying in Boston is exploring the cultural, educational, historical, and recreational offerings.

RESEARCH AT NORTHEASTERN UNIVERSITY

Research and scholarship are integral parts of Northeastern University's commitment to the intellectual growth and academic achievement of its students. Research activities span almost every academic field and include laboratory projects, theoretical studies, and technological applications.

Funding for research comes from federal and state government agencies, foundations, corporations, and the University itself. In recent years such industrial firms as Beckman, Analog Devices, EMC Corporation, Ford Motor Company, General Electric, and Lockheed have supported Northeastern's research programs. Currently, external grants and contracts exceed $36 million annually.

Northeastern's faculty numbers among its ranks some of the most distinguished scholars in their fields, and many have received such prestigious awards as Sloan Scholarships, Guggenheim Fellowships, National Institutes of Health Research Awards, Fulbright Scholarships, and a MacArthur Foundation grant. Faculty members lecture the world over, serve as consultants to industry and government agencies, participate on a variety of national and international committees, and are quoted frequently in the regional and national press on a wide range of subjects.

With the completion in the fall of 1996 of the $30 million, four story Egan Research Center, Northeastern now has the resources that benefit the high level of scientific research conducted here. It has increased by 50 percent the on-campus space allocated for research. It has enabled researchers in engineering, physics, chemistry and computer science to work together in the same and adjacent laboratory modules. With the construction of the Egan Research Center, Northeastern University possesses one of the finest research facilities in New England. It also houses a Technology Transfer Center that provides meeting space for major technical conferences.

Included in the center are the following Engineering College research laboratories:

- Computational Electromagnetics
- Computer Engineering
- Communications and Digital Signal Processing
- Mechanical Behavior of Materials
- Mechanical Engineering Metallurgy
- Microfabrication (Electron Devices)
- Microwave Materials
- Optical Science
- Plasma Science and Microelectronics
- Radar and Microwave Systems
- Manufacturing and Robotics
- Robotics and Vision Systems
- Advanced Microgravity Materials Processing

Research Centers and Institutes

Northeastern University operates a number of institutes and research centers to foster research efforts in areas that cross disciplinary boundaries. Some key units are:

- Center for Advanced Microgravity Materials Processing
- Center for Applied Social Research
- Barnett Institute of Chemical Analysis and Materials Science
- Center for Communications and Digital Signal Processing
- Center for Drug Targeting and Analysis
- Center for Electromagnetics Research
- Center for European Economic Studies
- Center for Labor Market Studies
- Center for Law and Computer Science
- Marine Science and Maritime Studies Center
- Center for Technology Management
- Center for Innovation in Urban Education
- Center for Vertebrate Studies
- Electron Microscopy Center

Financial Information

TUITION AND FEES

The tuition rate for students enrolled in the Graduate School of Engineering for the 1998/99 academic year is $465 per quarter hour of credit. Doctoral candidates making active use of University resources are charged an additional $600 per quarter residency for three quarters. (A continuation fee, equivalent to the tuition cost for one-half of one quarter hour of credit for Master of Science and Engineer Degrees and one quarter hour of credit for Doctorates, is charged to students who have completed their course requirements but not their thesis requirements.)

Full payment of tuition and other related charges are due by the beginning of each quarter. The following are accepted methods of payment:

- Check or Money Order made payable to Northeastern University
- Mastercard, Visa, American Express or Discover. Payments may be made in person or by calling our 24 hour automated charge line, (617) 373-2319 or 1-800-937-4067
- Enrollment in the Three Payment Option (described below)

Students are responsible for the prompt payment of all bills. If a bill has not been received by the first week of the quarter, please go to the Bursar's Office where a bill will be created for you.

Any discrepancies in your bill should be brought to the attention of the Bursar's Office. If there is a billing problem, pay the undisputed portion of the bill to avoid any additional late fees.

Three Payment Option

Northeastern University offers a three payment option plan. Information regarding this plan may be obtained at the Bursar's Office or by calling (617) 373-2270, (TTY) (617) 373-3881. There is a nominal fee for participation in this program. Applications along with the initial payment of 1/3 plus the fee are due the first Saturday of each quarter.

Tuition Reimbursement

Many companies do not pay the University directly but will reimburse their employees upon successful completion of the covered courses. In such cases, the student is responsible for full payment at the start of each quarter, or may select to use the Three Payment Option plan. Tuition may not be left unpaid pending employer reimbursement. Failure to make payments in accordance with these regulations will result in a late payment fee.

Tuition Paid for by Employers
In cases where payment is to be made directly by the employer to the University, the student must provide the Bursar's Office with a purchase order or statement from an officer of the company certifying that the company will pay the University directly. If there are stipulations associated with the payment agreement, such as a minimum grade level, the student must either pay the University directly or enroll in the Three Payment Option plan.

Refunds
Tuition refunds may be granted through the first four weeks of a quarter on the basis of the date appearing on the official withdrawal application filed with the Registrar's Office. Non-attendance does not constitute official withdrawal. Credit balances will be applied to future charges, unless the Bursar's Office receives other written instructions. Refunds will be credited according to the following schedule:

Official Withdrawal Filed Within:	**Percentage of Tuition Refunded:**
First week of the quarter	100%
Second week of the quarter	75%
Third week of the quarter	50%
Fourth week of the quarter	25%
Fifth week of the quarter	0%

Note: A different refund schedule may apply to courses that run less than a full quarter.

Delinquent Balances
In cases of student default on tuition payments, the student is liable for the outstanding tuition, as well as all reasonable collection costs and any legal fees incurred by the University during the collection process, and may be subject to monthly interest charges.

Note: Transcripts and other academic records will not be released until all financial obligations to the University have been met.

Health Service Waiver Process
The University provides hospital insurance for all students who have matriculated, carrying a course load of nine credits or more, or who are in a full-time program. This program is mandated by the Commonwealth of Massachusetts. You will be enrolled automatically in the University's plan, and $841.00 will be charged to your Northeastern account. Students who are covered under a comparable hospital insurance plan may waive the University offered insurance program by filing a waiver available at the Bursar's Office. Forms must be filed with the Bursar's Office, 254 Richard's Hall, Boston, Massachusetts, 02115, (617) 373-2270, by the deadline dates. *Waivers submitted after the deadline will not receive a full reversal of the Health Fee.*

For complete information regarding costs and resources please review *"A Hands on Approach to Tuition and Fees"* brochure. To obtain a copy, please contact the Bursar's Office at (617) 373-2270, or e-mail your request to **bursar@nufi1.finance.neu.edu**. Visit our Web site at **http://www.neu.edu/bursar**. *For automated account information, call (617) 373-8000, press 2 then 4 for Bursar student account information.*

FINANCIAL ASSISTANCE

Northeastern University offers graduate students a variety of means for obtaining financial assistance. In addition to various types of assistantships awarded by the individual graduate schools, the Graduate and Law Student Financial Services Office administers several forms of financial aid. A limited number of fellowships are also available to minority students.

Graduate Assistantships

Of particular interest to full-time graduate students is the variety of assistantships and fellowship programs. Awards are based primarily upon the applicant's prior academic performance. Assistantship positions are typically awarded for three quarters starting in the fall and continuing through spring, although occasionally one- or two-quarter appointments are available. Assistantship applications may be obtained in the Graduate School of Engineering office.

Stipended Graduate Assistantships require twenty hours of work per week. In return, the student receives a stipend currently valued at $12,450 for the nine-month period, September to June, plus a full tuition waiver. The stipend portion of the SGA is viewed as taxable income by the United States government. There are three categories of SGA appointments:

> *Administrative Assistantships* are provided by some of the administrative offices within the College of Engineering. The work performed by recipients of these positions typically involves administrative support of academic programs.
>
> *Research Assistantships* are available to those students who have a strong academic background and demonstrate an interest in and proficiency for research. These appointments are typically funded by research grants and the appointments are therefore contingent upon funding being available.
>
> *Teaching Assistantships* are awarded by academic departments and are available to students with a proficiency for teaching. These positions generally require the performance of teaching-related duties such as grading, conducting recitations and laboratories, and occasionally teaching undergraduate classes. Training at the English Language Center is mandatory for new teaching assistants whose first language is not English.

Northeastern University Tuition Assistantships require the performance of ten hours of work per week in exchange for a tuition waiver equivalent to eight credits of engineering courses each quarter. The United States government considers the tuition waiver to be taxable income as it is compensation for work performed. Typically this type of position requires the support of faculty in their teaching or research related activities.

Fellowship programs are available on a limited basis and are very competitive. Most fellowship programs administered by the University are open only to United States citizens or permanent residents. Fellowships have no work requirement, and may provide a tuition waiver, a stipend, or a combination of both.

Note: Assistantships and fellowships are considered a financial aid resource and may impact a student's award.

Acceptance Conditions for Graduate Assistantships

Northeastern University, which is a member of the Council of Graduate Schools of the United States, subscribes to the following resolution of the Council: Acceptance of an offer of financial aid (such as a graduate scholarship, fellowship, traineeship, or assistantship) for the next academic year by an actual or prospective graduate student completes an agreement which both student and graduate school expect to honor. In those instances in which the student accepts the offer before April 15 and subsequently desires to withdraw, the student may submit in writing a resignation of the appointment at any time through April 15. However, an acceptance given or left in force after April 15 commits the student not to accept another offer without first obtaining a written release from the institution to which a commitment has been made. Similarly, an offer by an institution after April 15 is conditional on presentation by the student of the written release from any previously accepted offer.

Financial Aid Programs

The Graduate and Law Student Financial Services Office offers several types of assistance to graduate students, primarily in the form of loans. The preferred deadline is March 1st, though students may apply later during the year. Even though students will not be awarded financial aid until they have been accepted into a degree granting program, many students choose to apply for aid before they have been offered admission to the Graduate School to expedite the process.

The Graduate and Law Student Financial Services Office requires that a student be enrolled in a minimum of 6 credits (8 for Engineering) to receive financial aid unless they are enrolled in a clinical practicum and/or doing a thesis/dissertation which is part of the program's requirements. If a student drops below half-time status, s/he may become ineligible, and have to return monies. Though international students are not eligible for Federal Government loans such as Perkins and Stafford loans, they are eligible for special loans such as the Teri loan.

Northeastern University requires that all applicants for financial aid (including loans) file a FAFSA in order to be eligible for consideration. The Graduate School Financial Aid application is also required. All financial aid application forms are available from the Graduate and Law Student Financial Services Office, Northeastern University, 410 Richards Hall, Boston, Massachusetts, 02115, (617) 373-5899, Fax (617) 373-5666, TTY (617) 373-5714,
or E-mail: **www.neu.edu/financial_aid/welcome.htm**.

Federal Perkins Loans

This program is available to full-time graduate students who show a high level of financial need. Repayment and interest do not begin until nine months after the student ceases to carry at least a half-time academic load. Repayment may be extended over a 10 year period with an interest rate of five percent per annum. No payments are required for up to three years while a borrower is serving in the Armed Forces, Peace Corps, VISTA, or while working as a full-time volunteer for a tax-exempt charitable organization performing service comparable to the service performed in Peace Corps or VISTA.

Federal Work-Study Program

This program is available to full-time graduate students who show financial need. It is designed to give students an opportunity to earn as much as $8.00 per hour working in jobs on or off campus in public or private nonprofit organizations. This program is administered solely by the Graduate and Law Student Financial Services Office and should not be confused with the University's Cooperative Education Program.

Federal Stafford Student Loan Program

(formerly the Guaranteed Student Loan)

The Federal Stafford Student Loan Program offers two types of student loans; subsidized and unsubsidized. The Subsidized Stafford Loan allows students who demonstrate financial need to borrow up to $8,500 each year to meet their educational expenses. The Federal Government pays the interest on a subsidized loan for students while they are enrolled on at least a half time basis (8 credits per quarter in the engineering program) and for the first six months thereafter. The Unsubsidized Stafford Loan allows qualified students who apply for aid to borrow $10,000 annually. Financial need is not a factor. The student is responsible for all interest payments, and may elect to pay both principal and interest, interest only, or to capitalize the interest during the in-school period. All qualified students may borrow up to $18,500 per year in any combination of subsidized and unsubsidized loans. The combined aggregate borrowing limit for undergraduate and graduate Stafford Loans is $138,500.

To be qualified for a Stafford Loan, a student must be a U.S. Citizen or eligible non-citizen accepted for enrollment, not be in default or owe a refund of any federal monies, and have completed all required financial aid application materials. Students must also complete a separate Federal Stafford Student Loan Application. Loan applications and information may be obtained from lending institutions, state guarantee agencies, or the Northeastern Graduate and Law Student Financial Services Office. Please note that students must be accepted into the engineering program and have received an Award Notification from the Northeastern Graduate and Law Student Financial Services Office prior to submitting a Stafford Loan Application.

Note: Assistantships and fellowships are considered a financial aid resource and may impact a student's award.

Scholarships

Northeastern University Minority Fellowships (NUMF) are to assist a limited number of minority students accepted for full-time study in the Graduate Schools of the University. The awards are made to students who demonstrate superior academic achievement and are competitive within each graduate school. Stipends cover tuition and fees.

Martin Luther King, Jr. Scholarships. A limited number of full-time Martin Luther King, Jr., Scholarships are available. These scholarships pay the recipient's full tuition and student center and health fees during the course of satisfactory graduate work. Further information and applications are available at the African-American Institute, Northeastern University, 40 Leon Street, Boston, Massachusetts, 02115.

Residence Hall Staff Positions

A limited number of residence staff positions in housing facilities are available each year. Appointments carry a minimum compensation of room and board. Further information may be obtained from the Residential Life Office, Northeastern University, 104 Ell Building, Boston, Massachusetts, 02115.

Graduate Cooperative Education

The Graduate Programs in Engineering offer the opportunity to Master of Science Degree students for Cooperative Education. The number of offerings available to domestic students is limited and there are further restrictions on international student placements. Students in the cooperative plan of graduate education may follow either an alternating or a parallel schedule, according to availability.

The Graduate Engineering student may apply for Co-op during the fall quarter of his/her first year of study. If accepted into the Co-op Program, the student is eligible for initial placement during the spring and summer quarters of the same academic year. Eligibility requirements include: master's degree candidate; full-time enrollment; regular degree status and a grade point average of at least a B (3.000). Students who hold a stipended assistantship, or any similar type award, are not allowed to participate in the quarter(s) during which the award is effective.

The alternating schedule is sequenced to include full-time co-op employment for three- or six-month periods inter-spaced with periods of classroom study on a full-time academic schedule of 12 to 14 quarter hours minimum each quarter. The parallel schedule allows the graduate student to work simultaneously, for approximately 20 hours per week, while carrying a minimum academic load of eight quarter hours per quarter.

Graduate School of Engineering

GENERAL INFORMATION

The Graduate School of Engineering offers degree programs designed to help students prepare themselves for technical positions in industrial organizations, government laboratories, research laboratories, and educational institutions.

In addition to extensive day graduate programs, the Graduate School of Engineering offers Master of Science, and Doctoral Degree programs on a part-time basis in the evening. An interdisciplinary Doctor of Philosophy is also available for graduate students whose interests overlap two or more departments. All full-time day graduate programs are offered at the Boston campus. The evening graduate programs offered through the Department of Electrical and Computer Engineering and in Industrial Engineering, Information Systems, and Engineering Management are available at both the Boston campus and the suburban Burlington campus. The other evening graduate programs are offered at the Boston campus only.

Northeastern University awards credit on a quarter-hour basis, with one quarter-hour credit roughly equivalent to three-fourths of a semester hour. The Master of Science degree requires a minimum of forty to forty-eight quarter-hour credits, depending on the specific program selected. In some cases, depending upon academic background, prerequisite courses are required. Part-time students who normally carry four quarter hours each term can generally complete their programs in three and a half to four years, while full-time students, who may take twelve to sixteen quarter hours each term, may earn their degrees in as little as one year. However, full-time students receiving some form of assistantship or who are enrolled in the co-op plan or the Master of Science in Information Systems program must usually devote two years to completing their academic requirements.

The Master of Science degree with specification is granted to students who have earned a baccalaureate degree in the same engineering discipline as their graduate program. However, students who are admitted to the Computer Systems Engineering, Engineering Management, Information Systems, and Operations Research programs may be exempted from this general policy and may earn the specified degree regardless of their undergraduate training. Students holding undergraduate degrees in disciplines that do not correspond to their graduate program or that have been conferred by colleges outside the United States are usually awarded the Master of Science degree without specification upon completion of their program requirements.

SPECIAL PROGRAMS IN ENGINEERING

Women in Information Systems

The Women in Information Systems program leads to a Master of Science in Information Systems degree. The program is designed for women with technical as well as non-technical degrees who seek the opportunity for a career move into computer applications and software fields.

The program's goal is to provide a complete career transition in a short time frame by building new technical skills on the knowledge and professional experience base that students have previously acquired. The program begins with an initial full-time academic commitment of nine months. Students are then offered help in locating jobs where they will be expected to work forty hours a week earning industry-competitive, entry-level salaries while completing their Master of Science degree on a part-time basis. The students may elect to complete all MSIS degree requirements on a full-time basis.

Network Northeastern

Network Northeastern uses the microwave-based Instructional Television Fixed Service (ITFS) system to broadcast courses to subscriber companies and to the Burlington and Dedham campuses. The network telecasts live classroom instruction from the Boston campus to remote sites where students interact with instructors via a telephone-based talkback system. Class materials are delivered via courier service, U.S. mail, facsimile, or electronic mail.

Network Northeastern currently broadcasts graduate courses in electrical and computer engineering, mechanical engineering, industrial engineering, engineering management, computer systems engineering, information systems, and operations research to over thirty local corporations. Network Northeastern also delivers graduate level and short courses to corporations throughout the U.S. via satellite. Further information may be obtained from Network Northeastern, Northeastern University, 328 Columbus Place, Boston, Massachusetts, 02115, (617) 373-5620, or by viewing our web site: **www.neu.edu/network-nu**.

INTERDISCIPLINARY DOCTOR OF PHILOSOPHY

The Graduate School of Engineering offers the opportunity for an interdisciplinary doctoral program involving substantial work in two or more departments. A written proposal describing the areas of proposed study and research should be submitted with the student's application. Interdisciplinary study requires favorable recommendation by the sponsoring doctoral degree-granting department and approval by authorized representatives of the graduate study committees of the departments appropriate to the disciplines covered by the student's proposal. The sponsoring department is the registration base of the student.

Formation of Interdisciplinary Committee

A student who has been accepted for interdisciplinary study must obtain the consent of an advisor who will direct his or her doctoral thesis. This advisor, who may or may not be a member of the registration department, will be chairman of the interdisciplinary committee for this student. A second member will be appointed from the registration department by its chairman. These two members will obtain one or more additional members or request the director of the graduate school to do so. At least two departments must be represented on the committee, and a majority of the committee must come from doctoral degree-granting departments. The chairman of the registration

department will notify the Director of the Graduate School of the membership of the committee as soon as arrangements are complete.

Duties of Interdisciplinary Committee

A member of the interdisciplinary committee who is also a member of the registration department will serve as the registration officer to approve the course registration for the student. A copy of the approved course registration must also be filed with the other committee members and with the graduate study committee of the registration department.

The interdisciplinary committee will be responsible for the administration of the qualifying examination, language examination, approval of the dissertation, and comprehensive examination. This committee must also certify to the registration department the completion of the requirements for the award of the doctoral degree.

The interdisciplinary committee must assure that the program of the student represents standards comparable to those of the registration department and that the program is not so broad that it has inadequate depth in any area.

The student's program may be reviewed at any time by the Director of the Graduate School to determine whether objectives of the program are being met.

Department of Chemical Engineering

The Department of Chemical Engineering offers the degrees of Master of Science in Chemical Engineering, Master of Science without specification, and Doctor of Philosophy. The Master of Science degree in Chemical Engineering may be pursued on either a full-time or a part-time basis. A full-time student may apply for participation in the Cooperative Plan. The Master of Science degree without specification must be pursued on a continuous full-time basis. The Doctor of Philosophy degree is pursued on a continuous full-time basis consistent with the residence requirements for the degree.

Full-time Master of Science degree students and Doctoral candidates are able to select thesis topics from a diverse range of faculty research interests. Graduate student seminars are held on a regular basis and provide an interactive forum for learning about departmental research and exchanging ideas. Most courses are offered in the late afternoon or early evening to make them readily accessible to part-time students pursuing full-time industrial careers.

Master of Science degree students wishing to switch their status from part-time to full-time must notify the Chemical Engineering Department and make formal petition to the Graduate School of Engineering. Such requests are usually granted for the full-time program to begin in the fall quarter. Please refer to the regulations of the Graduate School of Engineering for information on academic and administrative policies.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of 40 quarter hours of academic work is required of all students. A thesis of ten quarter hours of credit and one seminar course are required of all continuous and cooperative full-time students who qualify for the Master of Science in Chemical Engineering, in addition to the required courses. All Master of Science degree students must present a seminar on their thesis work to at least three department faculty before final acceptance. The sequence of courses which students take on this plan is established by their advisor. Part-time students may progress according to their abilities within the seven year time limit. A minimum of 44 quarter hours of academic course work is required for part-time students. The thesis and seminar course are not required for part-time students and unspecified Master of Science degree candidates.

A Master of Science in Chemical Engineering will be awarded to those students with a Bachelor of Science in Chemical Engineering or a closely-allied engineering field. Students with a Bachelor of Science degree in other engineering or related science fields and an appropriate background of preparation may qualify for the degree of Master of Science with specification. Such students are required to complete supplementary undergraduate work, which is not included in the minimum course requirements, on a full-time (non-cooperative education) basis.

Course Requirements	Thesis Option	Non-Thesis Option
Required Core Courses	12 QH	12 QH
Master of Science Thesis	10 QH	0 QH
Seminar	2 QH	0 QH
Elective Courses**	16 QH	32 QH
Minimum Quarter Hours Required*	40 QH	44 QH

* exclusive of any preparatory courses

** students may complete a maximum of 10 QH (Thesis Option) or 12 QH (Non-Thesis Option) of course work outside of the Chemical Engineering Department with approval of the Chemical Engineering Department

Required Core Courses (2QH equivalents are in parentheses)

				Credits
CHE	3300	(3301,3302)	Chemical Engineering Mathematics	4
CHE	3310	(3311,3312)	Chemical Engineering Thermodynamics	4
CHE	3320	(3321,3322)	Separation Processes	4
CHE	3330	(3331,3332)	Chemical Process Control	4
CHE	3400	(3401,3420)	Advanced Chemical Engineering Calculations	4
CHE	3540	(3541,3542)	Advanced Process Design Concepts	4
Master of Science Thesis CHE 3860 (10QH), 3861 (4QH), 3862 (2QH)				10
Seminar CHE 3691				2

Elective Courses

CHE	3340	(3341,3342)	Heterogeneous Catalysis	4
CHE	3350	(3351,3352)	Chemical Process Heat Transfer	4
CHE	3410	(3411,3412)	Numerical Techniques in Chemical Engineering	4
CHE	3430	(3431,3432)	Chemical Data Estimation	4
CHE	3450		Analytical and Numerical Techniques	4
CHE	3500	(3501,3502)	Transport Phenomena	4
CHE	3510	(3511,3512)	Modeling and Simulation of Chemical Process	4
CHE	3520	(3521,3522)	Computer Process Control	4
CHE	3530	(3531,3532)	Adv. Mgmt. Techniques in the Chemical Industry.	4
CHE	3543		Advanced Plant Design Concepts	2
CHE	3560	(3561,3562)	Fluid Mechanics	4
CHE	3600	(3601,3602)	Polymer Science	4
CHE	3620	(3621,3622)	Principles of Polymerization	4
CHE	3630	(3631,3632)	Chemical Process Pollution Control	4
CHE	3659		Solar Energy Thermal Processes	2
CHE	3663	(3664,3665)	Fundamentals of Polymer Processing	4
CHE	3670	(3701,3702)	Special Topics in Chemical Engineering	4
CHE	3671	(3672,3673)	Kinetics of Chemical Processes	4
CHE	3680		Corrosion Fundamentals	2

THE DOCTOR OF PHILOSOPHY DEGREE

The Chemical Engineering Department offers the degree of Doctor of Philosophy on a continuous full-time basis. The following sections constitute the requirements for the doctoral program. Each student admitted to the program will initially have the status of *Doctoral Student*. A doctoral student who has completed the equivalent of an MS program in chemical engineering or 40 quarter hours of

graduate work with satisfactory grades may become a *Doctoral Candidate* upon successful completion of the *Doctoral Qualifying Examination.* After candidacy has been established, a candidate must complete a dissertation under the direction of a Dissertation Advisor and a program of academic course work. To receive a Ph.D. degree a candidate must also pass a *Final Oral Examination.*

Qualifying Examination

Successful completion of the Doctoral Qualifying Examination is the minimum required for consideration as doctoral degree candidate. The qualifying examination includes both written and oral parts. The written part is normally given in the winter quarter. The oral examination will test general comprehension and is normally given at the time of the dissertation topic proposal presentation. The written examination, in general, will cover the following areas: Thermodynamics, Kinetics and Reactor Design, Process Control, Unit Operations (including Transport Phenomena), Process Design, and Applied Chemistry.

Course Requirements

A minimum of 60 quarter hours of academic course work beyond the bachelor of science degree in chemical engineering is required. The 60 quarter hours must include, at least, 24 quarter hours of academic course work (exclusive of thesis and seminars) taken at Northeastern University. All of the core courses for the specified masters degree must be included in the students academic graduate course work. The course requirements, in addition to the minimum requirements for establishing degree candidacy, will be determined by the departmental graduate committee.

Language Requirement

There is no foreign language requirement for the Doctor of Philosophy degree. The candidate must be proficient in technical writing and oral presentation in the English language. Appropriate course work may be required by the departmental graduate committee.

Residence Requirement

The residence requirement is satisfied by completing one academic year of full-time graduate studies during 3 consecutive academic quarters after successful completion (passing) of the Doctoral Qualifying Examination. Additional academic course work (exclusive of thesis and seminars) may be required and completed during this period. However, it is expected that at least two years of full-time graduate study will be required beyond the Master of Science degree.

Dissertation Prospectus/Outline

After passing the qualifying examination, the doctoral degree candidate must prepare a dissertation prospectus/outline depicting the research on an engineering problem which will be conducted, analyzed and presented in the dissertation. The cover sheet is signed by each member of the dissertation committee to indicate approval of the topic and its plan of execution.

Comprehensive Examination

The comprehensive examination is combined with the final oral examination and is given after the dissertation has been completed and approved by the dissertation advisor. This examination is based upon a defense of the subject matter of the dissertation.

Final Oral Examination

The final oral examination is taken after completion of all other requirements for the degree. The final oral examination will include the subject matter of the doctoral dissertation and significant developments in the field of the dissertation work. Other fields may be included if recommended by the examination committee.

Dissertation

After degree candidacy has been established, a candidate must complete a dissertation which embodies the results of extended original research and includes material suitable for publication. An individual may choose his/her dissertation topic and supervisor upon becoming a doctoral student. In most cases selection of topic will be made immediately after the student has established candidacy for the Ph.D. degree. The student will be expected to discuss Ph.D. dissertation topic offerings with the faculty. After these discussions, the student shall notify the advisor, the department head, and the chairman of the departmental graduate committee in writing of his/her choice of dissertation topic and advisor. The chairman of the departmental graduate committee, after consultation with the advisor, shall appoint an appropriate *Doctoral Dissertation Committee.* This committee shall be kept informed of the progress of the dissertation and will approve the dissertation in its final form.

FACULTY

Ralph A. Buonopane, Chairman

Professors

Sacco Jr., Albert, PhD, Massachusetts Institute of Technology; catalysis, advanced microgravity materials processing, carbon filaments

Willey, Ronald, J., PhD, University of Massachusetts, Amherst; heterogeneous catalysis

Williams, John A., PhD, Case Western Reserve University; fuels

Wise, Donald L., PhD, University of Pittsburgh; biotechnology, biomaterials, bioconversions

Associate Professors

Barabino, Gilda A., PhD, Rice University; biomedical/biochemical

Buonopane, Ralph A., PhD, Northeastern University; heat and mass transfer

Goodwin, Bernard M., ScD, Massachusetts Institute of Technology; computer applications, applied mathematics

Stewart, Richard R., PhD, Clemson University; process control

PROGRAM ADVISORS

MS Specified	(A-Z) Prof. Willey
MS Unspecified	(A-Z) Prof. Buonopane
PhD Program	(A-Z) Prof. Sacco

Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering sheets to determine the courses that are actually offered in any given quarter and the day and time.

CHE 3300 Chemical Engineering Mathematics (4QH)
Fall Quarter, Alternating Years
Formulation and solution of problems involving advanced calculus as they arise in chemical engineering situations. Methods covered will include ordinary differential equations, series solutions, complex variables. Laplace transforms, partial differential equations, and matrix operations. Emphasis will be placed on methods for formulating the problems. It will be assumed that the student has been exposed to some of these topics in appropriate mathematics courses. *Prep. BS Degree in Chemical Engineering including mathematical analysis.*

CHE 3301 Chemical Engineering Mathematics 1 (2QH)
Fall Quarter, As Announced
CHE 3301 and CHE 3302 cover the same material with the same prerequisites as CHE 3300, but in two 2QH courses.

CHE 3302 Chemical Engineering Mathematics 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3301. *Prep. CHE 3301.*

CHE 3310 Chemical Engineering Thermodynamics (4QH)
Winter Quarter, Alternating Years
Classical thermodynamics as a method of approach to the analysis of processes of interest to chemical engineers. A study of phase equilibria involving the various states of matter; prediction and correlation of physical, chemical, and transport properties of gases and liquids; elementary concepts of quantum and statistical mechanics to interpret the empirical properties of classical thermodynamics. Fundamental principles are reviewed to the extent needed. *Prep. BS Degree in Chemical Engineering.*

CHE 3311 Chemical Engineering Thermodynamics 1 (2QH)
Winter Quarter, As Announced
CHE 3311 and CHE 3312 cover the same material with the same prerequisites as CHE 3310, but in two 2QH courses.

CHE 3312 Chemical Engineering Thermodynamics 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3311. *Prep. CHE 3311.*

CHE 3320 Separation Processes (4QH)
Spring Quarter, Alternating Years
Calculation and design methods used in processes involving mass transfer. Topics covered include vapor liquid equilibria for binary and multicomponent systems, multicomponent distillation, absorption and extraction. Emphasis is placed on methods and techniques which are common to many separation processes. *Prep. BS Degree in Chemical Engineering.*

CHE 3321 Separation Processes 1 (2QH)
Winter Quarter, As Announced
CHE 3321 and CHE 3322 cover the same material with the same prerequisites as CHE 3320, but in two 2QH courses.

CHE 3322 Separation Processes 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3321. *Prep. CHE 3321*

CHE 3330 Chemical Process Control (4QH)
Fall Quarter, Alternating Years
Modeling for process control, degrees of freedom analysis, linearization and state-variable format for process models, simulation of single and multivariable control systems, controller design by direct synthesis and internal model control methods, feed forward and cascade control, pairing manipulated and controlled variables in multivariable control. *Prep. Admission to Graduate School of Engineering.*

CHE 3331 Chemical Process Control 1 (2QH)
Fall Quarter, As Announced
CHE 3331 and CHE 3332 cover the same material with the same prerequisites as CHE 3330, but in two 2QH courses.

CHE 3332 Chemical Process Control 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3331. *Prep. CHE 3331.*

CHE 3340 Heterogeneous Catalysis (4QH)
Winter Quarter, Alternating Years
Experimental methods required for determining the surface area and pore structure of catalyst carriers are discussed. These structural characteristics are utilized to estimate mass and heat transport rates within porous catalysts in order to determine their effectiveness with respect to chemical reaction. Mechanisms for chemical poisoning of catalysts are also analyzed. Reactions of practical interest are used to illustrate the applications of heterogeneous catalysis to modern chemical processing problems. *Prep. BS Degree in Chemical Engineering.*

CHE 3341 Heterogeneous Catalysis 1 (2QH)
Winter Quarter, As Announced
CHE 3341 and CHE 3342 cover the same material with the same prerequisites as CHE 3340, but in two 2QH courses.

CHE 3342 Heterogeneous Catalysis 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3341. *Prep. CHE 3341.*

CHE 3350 Chemical Process Heat Transfer (4QH)
Spring Quarter, Alternating Years
Empirical methods and calculations used to design heat transfer equipment for the chemical process industries. Review of basic heat transfer principles. Shell-and-tube calculations for liquid and/or vapor phase heat transfer. Direct contact and other special heat exchanger applications. *Prep. BS Degree in Chemical Engineering.*

CHE 3351 Chemical Process Heat Transfer 1 (2QH)
Winter Quarter, As Announced
CHE 3351 and CHE 3352 cover the same material with the same prerequisites as CHE 3350, but in two 2QH courses.

CHE 3352 Chemical Process Heat Transfer 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3351. *Prep. CHE 3351.*

CHE 3400 Advanced Chemical Engineering Calculations (4QH)
As Announced
Fundamental process principles leading to an understanding of the stoichiometric principles of chemical process plants. The study of complex material and energy balances is undertaken with the view to apply these principles to actual large chemical plant conditions. *Prep. BS Degree in Chemical Engineering including differential equations.*

CHE 3401 Advanced Chemical Engineering Calculations 1 (2QH)
As Announced
CHE 3401 and CHE 3402 cover the same material with the same prerequisites as CHE 3400, but in two 2QH courses.

CHE 3402 Advanced Chemical Engineering Calculations 2 (2QH)
As Announced
Continuation of CHE 3401. *Prep. CHE 3401.*

CHE 3410 Numerical Techniques in Chemical Engineering (4QH)
Fall Quarter, As Announced
Digital computer applications to chemical engineering problems. Topics covered include location of roots of linear and nonlinear equations, numerical integration, and curve-fitting techniques with emphasis on the numerical solution of ordinary and partial differential equations and on the subject of linear algebra. *Prep. BS Degree in Chemical Engineering.*

CHE 3411 Numerical Techniques in Chemical Engineering 1 (2QH)
Fall Quarter, As Announced
CHE 3411 and CHE 3412 cover the same material with the same prerequisites as CHE 3410, but in two 2QH courses.

CHE 3412 Numerical Techniques in Chemical Engineering 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3411. *Prep. CHE 3411.*

CHE 3430 Chemical Data Estimation (4QH)
As Announced
Methods of obtaining physical and thermodynamic properties of chemical compounds and systems without resorting to laboratory investigation. Latest empirical relationships and physical and thermodynamics laws are introduced to obtain data for plant design and other chemical and engineering uses. *Prep. BS Degree.*

CHE 3431 Chemical Data Estimation 1 (2QH)
Fall Quarter, As Announced
CHE 3431 and CHE 3432 cover the same material with the same prerequisites as CHE 3430, but in two 2QH courses.

CHE 3432 Chemical Data Estimation 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3431. *Prep. CHE 3431.*

CHE 3450 Analytical and Numerical Techniques (4QH)
As Announced
For students interested in solving comprehensive problems using computer methods. Problems solved in the course will be based on the interest of the students and staff and will be individual. *Prep. BS Degree and knowledge of digital computer programming.*

CHE 3500 Transport Phenomena (4QH)
Winter Quarter, As Announced
Momentum rate conservation equations for steady-state fluid flow in two-dimensional boundary layers are presented and solved to obtain the fluid velocity profiles. These results are utilized in the consideration of heat and mass transfer phenomena at a fluid-solid interface. The development of surface renewal theory is presented and applied to the description of heat and mass transfer phenomena. *Prep. BS Degree in Chemical Engineering.*

CHE 3501 Transport Phenomena 1 (2QH)
Winter Quarter, As Announced
CHE 3501 and CHE 3502 cover the same material with the same prerequisites as CHE 3500, but in two 2QH courses.

CHE 3502 Transport Phenomena 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3501. *Prep. CHE 3501.*

CHE 3510 Modeling and Simulation of Chemical Process (4QH)
Winter Quarter, Alternating Years
Use of special purpose and general purpose computer programs in solving the steady-state material and energy balances of chemical processes. Includes related background material which may be applied to these computer programs such as convergence acceleration for calculations involving recycle streams, tearing recycle streams for iteration on minimum number of streams and minimum number of parameters, and algorithms for design variable selection. *Prep. Graduate standing in Chemical Engineering.*

CHE 3511 Modeling and Simulation of Chemical Process 1 (2QH)
Winter Quarter, As Announced
CHE 3511 and CHE 3512 cover the same material with the same prerequisites as CHE 3510, but in two 2QH courses.

CHE 3512 Modeling and Simulation of Chemical Process 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3511. *Prep. CHE 3511.*

CHE 3520 Computer Process Control (4QH)
Winter Quarter, Alternating Years
Computer control hardware and software. Z-transform, pulse transfer functions, and data holds. Open and closed-loop response and design of sampled data systems. Computer control algorithms. Digital simulation of sampled data systems. *Prep. Graduate standing in Chemical Engineering or permission.*

CHE 3521 Computer Process Control 1 (2QH)
Winter Quarter, As Announced
CHE 3521 and CHE 3522 cover the same material with the same prerequisites as CHE 3520, but in two 2QH courses.

CHE 3522 Computer Process Control 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3521. *Prep. CHE 3521.*

CHE 3530 Advanced Management Techniques in the Chemical Industry (4QH)
Fall Quarter, Alternating Years
Management techniques applied to the chemical industry. Special attention to management of research organizations and to management of engineering services, such as design, computer, and related activities. *Prep. Graduate standing.*

CHE 3531 Advanced Management Techniques in the Chemical Industry 1 (2QH)
Fall Quarter, As Announced
CHE 3531 and CHE 3532 cover the same material with the same prerequisites as CHE 3530, but in two 2QH courses.

CHE 3532 Advanced Management Techniques in the Chemical Industry 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3531. *Prep. CHE 3531.*

CHE 3540 Advanced Process Design Concepts (4QH)
Spring Quarter, Alternating Years
Techniques and approaches used in the development of new or improved processes. Topics include establishment of process bases, use of process simulators in design, optimization and evaluation of alternatives, and preliminary equipment design and cost estimating techniques. *Prep. BS Degree in Chemical Engineering.*

CHE 3541 Advanced Process Design Concepts 1 (2QH)
Fall Quarter, As Announced
CHE 3541 and CHE 3542 cover the same material with the same prerequisites as CHE 3540, but in two 2QH courses.

CHE 3542 Advanced Process Design Concepts 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3541. *Prep. CHE 3541.*

CHE 3543 Advanced Plant Design Concepts (2QH)
Spring Quarter, As Announced
Modern approaches to plant design: computer-oriented design, analysis and simulation of chemical processes, use of strategy decision making in design, advanced scheduling and planning techniques. *Prep. BS Degree in Chemical Engineering.*

CHE 3560 Fluid Mechanics (4QH)
Fall Quarter, Alternating Years
Discussion of statics, kinematics, and stress concepts associated with fluids. Formation of the general equations of motion with application to laminar and turbulent flow. Topics on boundary layer theory and compressible flow are included. *Prep. BS Degree in Chemical Engineering.*

CHE 3561 Fluid Mechanics 1 (2QH)
Fall Quarter, As Announced
CHE 3561 and CHE 3562 cover the same material with the same prerequisites as CHE 3560, but in two 2QH courses.

CHE 3562 Fluid Mechanics 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3561. *Prep. CHE 3561.*

CHE 3600 Polymer Science (4QH)
Fall Quarter, Alternating Years
Basic concepts of polymers, thermodynamics of polymer solutions and measurement of molecular weight. Physical and chemical testing of polymers. Crystallinity in polymers and rheology of polymers. Physical and chemical properties of polymers. Mechanisms and conditions for polymerization of polymers including step-reaction, addition and copolymerization. Discussion of carbon-chain polymers, fibers and fiber technology. *Prep. BS Degree in Chemical Engineering or Chemistry.*

CHE 3601 Polymer Science 1 (2QH)
Fall Quarter, As Announced
CHE 3601 and CHE 3602 cover the same material with the same prerequisites as CHE 3600, but in two 2QH courses.

CHE 3602 Polymer Science 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3601. *Prep. CHE 3601.*

CHE 3620 Principles of Polymerization (4QH)
Fall Quarter, Alternating Years
Introduction to polymers and polymer properties. Mechanisms of polymerization including step polymerization, radical chain polymerization, emulsion polymerization, ionic-chain polymerization, chain copolymerization and ring-opening polymerization. Stereo chemistry of polymerization and synthetic reactions of polymers. Applications to reactor design of industrially important polymers. *Prep. Graduate standing in Chemical Engineering.*

CHE 3621 Principles of Polymerization 1 (2QH)
Fall Quarter, As Announced
CHE 3621 and CHE 3622 cover the same material with the same prerequisites as CHE 3620, but in two 2QH courses.

CHE 3622 Principles of Polymerization 2 (2QH)
Winter Quarter, As Announced
Continuation of CHE 3621. *Prep. CHE 3621.*

CHE 3630 Chemical Processes of Pollution Control (4QH)
Spring Quarter, Alternating Years
The basic fundamentals for handling environmental problems in the chemical process industries. Water quality requirements and industrial waste characteristics; wastewater treatment processes applicable to environmental engineering; biological treatment processes and equipment; comprehensive design problems involving biological and tertiary treatment; the economics of water treatment and reuse. *Prep. Graduate standing in Chemical Engineering.*

CHE 3631 Chemical Processes of Pollution Control 1 (2QH)
Winter Quarter, As Announced
CHE 3631 and CHE 3632 cover the same material with the same prerequisites as CHE 3630, but in two 2QH courses.

CHE 3632 Chemical Processes of Pollution Control 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3631. *Prep. CHE 3631.*

CHE 3659 Solar Energy Thermal Process (2QH)
Fall Quarter
Fundamental thermal processes involved in obtaining useful heat from flat-plate solar collectors. The components required in an active solar energy collection system are analyzed and the economics of the system are considered. *Prep. BS Degree.*

CHE 3663 Fundamentals of Polymer Processes (4QH)
Winter Quarter, Alternating Years
Transport properties of polymer solutions and polymer melts. Modeling and design of polymer processing equipment. Flow models for processes involving heat, mass, and/or momentum transfer. Analysis of flow stability and elastic phenomena. Applications to the design of equipment for extrusion, calendering, coating, fiber spinning, tubular film blowing, injection molding and mixing. *Prep. Graduate standing in Chemical Engineering.*

CHE 3664 Fundamentals of Polymer Processes 1 (2QH)
Winter Quarter, As Announced
CHE 3664 and CHE 3665 cover the same material with the same prerequisites as CHE 3663, but in two 2QH courses.

CHE 3665 Fundamentals of Polymer Processes 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3664. *Prep. CHE 3664.*

CHE 3670 Special Topics in Chemical Engineering (4QH)
As Announced
Topics of interest to the staff member conducting this class are presented for advanced study. A student may not take more than one Special Topics course with any one instructor. *Prep. Permission of Department staff.*

CHE 3671 Kinetics of Chemical Processes (4QH)
Spring Quarter, Alternating Years
The theoretical foundations for the analysis of elementary chemical reaction rates, such as collision theory, particle dynamics, and transition state theory are presented. Consideration is given to the theory of mono-molecular reactions and the effect of solvent and electrostatic forces on liquid phase reaction rates. Homogeneous catalysis and selected free-energy correlations are covered. *Prep. BS Degree in Chemical Engineering.*

CHE 3672 Kinetics of Chemical Processes 1 (2QH)
Winter Quarter, As Announced
CHE 3672 and CHE 3673 cover the same material with the same prerequisites as CHE 3671, but in two 2QH courses.

CHE 3673 Kinetics of Chemical Processes 2 (2QH)
Spring Quarter, As Announced
Continuation of CHE 3672. *Prep. CHE 3672.*

CHE 3680 Corrosion Fundamentals (2QH)
As Announced
Economic factors, basic theories, types, behaviors of specific systems, and protection against corrosion are studied. Wherever possible, engineering applications of the principles are emphasized. *Prep. BS Degree*

CHE 3691 Seminar (2QH)
Any Quarter
Topics of an advanced nature are presented by staff, outside speakers, and students in the graduate program. This course must be attended by all master's degree candidates. *Prep. Graduate standing in Chemical Engineering.*

CHE 3701 Special Topics in Chemical Engineering 1 (2QH)
Any Quarter
Topics of interest to the staff member are presented for advanced study. A student may take this course and its continuation in CHE 3702 with the same instructor.

CHE 3702 Special Topics in Chemical Engineering 2 (2QH)
A continuation of CHE 3701

CHE 3798 Masters Continuation (0QH)
Any Quarter

CHE 3799 PhD Continuation (0QH)
Any Quarter

CHE 3860 Thesis (Master's Degree) (10QH)
Any Quarter
Analytical and/or experimental work conducted under the supervision of the department. Ten QH maximum credit for thesis. Students normally register in CHE 3861 or CHE 3862. *Prep. Graduate standing in Chemical Engineering.*

CHE 3861 Thesis (Master's Degree) (4QH)
Any Quarter

CHE 3862 Thesis (Master's Degree) (2QH)
Any Quarter

CHE 3880 Thesis (PhD Degree) (0QH)
Any Quarter
Theoretical and experimental work conducted under the supervision of the department. *Prep. Admission to doctoral program in Chemical Engineering.*

Department of Civil and Environmental Engineering

The Department of Civil and Environmental Engineering offers degree programs in construction management, environmental, geotechnical/geoenvironmental, structures, and transportation engineering on the Master of Science and PhD levels.

The Master of Science degree requirements may be completed on a full-time or part-time basis. In either case, the student must meet with his/her faculty advisor in the first quarter of study to arrange for an appropriate sequence of courses that will satisfy the degree requirements.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of forty quarter hours of credit including four quarter hours for a Master of Science report or eight quarter hours for a Master of Science thesis with a minimum overall grade point average of 3.00 is required in all programs. With the approval of the department, graduate courses in other departments may be substituted for certain courses. Please refer to the regulations of the Graduate School of Engineering for information on academic and administrative policies.

Students holding a BSCE degree who successfully complete program requirements will receive a Master of Science in Civil Engineering. An unspecified Master of Science degree will be awarded to those students who do not hold a BSCE degree.

Construction Management

The Construction Management program consists of required core courses primarily from the Civil and Environmental Engineering Department, complemented by electives from Civil and Environmental Engineering, the Department of Mechanical, Industrial and Manufacturing Engineering, or from the Graduate School of Business Administration. Based on proven proficiency in given areas, certain required core courses may be waived and replaced with alternative courses. In addition to the required core, students choose one or a combination of the following program options: construction and engineering, systems engineering, and/or business management. Each student is required to prepare a program of study which must be reviewed and approved by a faculty advisor during initial registration. Graduate courses not currently listed as technical electives may also be approved as technical electives by the student's advisor, provided they are consistent with the student's program.

Course Requirements	With Report	With Thesis
Required Core Courses	21 QH	21 QH
Master of Science Report or Thesis	4 QH	8 QH
Elective Courses	16 QH	12 QH
Minimum Quarter Hours Required*	41 QH	41 QH

* exclusive of any preparatory courses

Required Core Courses			Credits
CIV	3101	Applied Probability	4
CIV	3132	Engineering Statistics	2
CIV	3201	Construction Management	4
CIV	3202	Legal Aspects of Civil Engineering	4
CIV	3245	Construction Seminar	2
CIV	3252	Construction Project Organization and Control	2
ACC	3301	Financial and Managerial Accounting	3
or ACC	3820	Financial Accounting	3
Master of Science Report CIV 3850			4
or Master of Science Thesis CIV 3860			8

The remaining 16 or 12 elective quarter hours of course work must be selected from the following list: (electives do not have to be chosen from only one area of emphasis)

Construction and Engineering Emphasis

CIV	3203	Construction Equipment and Modeling	4
CIV	3401	Advanced Soil Mechanics	4
CIV	3402	Advanced Foundation Engineering	4
CIV	3508	Advanced Materials	4

Business Management Emphasis

FIN	3301	Financial Analysis	3
FIN	3916	Capital Investment Decision Analysis	3
MIM	3204	Engineering/Organizational Psychology	4
MIM	3207	Financial Management for Engineers	4

Systems Engineering Emphasis

MIM	3102	Planning and Managing Information Systems Development	4
MIM	3104	Data Structures	4
MIM	3115	Introduction to Software Engineering and Computer Technology	4
MIM	3122	PC Architecture and System Programming	4
MIM	3128	Database Management Systems	4
MIM	3129	Expert Systems in Engineering	4
MIM	3425	Reliability Analysis and Risk Assessment	4
MIM	3503	Simulation Methodology and Applications	4
MIM	3524	Multi-Criteria Decision Making	4
MIM	3530	Operations Research 1	4

Environmental Engineering

The Graduate Program in Environmental Engineering consists of required core courses and elective courses as described below. With the approval of the program advisor, students may take other graduate courses in civil engineering, in other engineering disciplines, or in other colleges at Northeastern.

Course Requirements

	With Report	With Thesis
Required Core Courses	18 QH	18 QH
Master of Science Report or Thesis	4 QH	8 QH
Elective Courses	18 QH	14 QH
Minimum Quarter Hours Required*	40 QH	40 QH

* exclusive of any preparatory courses

Required Core Courses

			Credits
CIV	3312	Environmental Chemistry	4
CIV	3318	Water and Wastewater Treatment	4
CIV	3321	Environmental Biological Processes	4
CIV	3327	Environmental Laboratory (or 3325 & 3326)	4
CIV	3332	Environmental Computer Applications	2
		Master of Science Report CIV 3850	4
or		Master of Science Thesis CIV 3860	8

The remaining 18 or 14 quarter hours of elective course work is to be selected from three elective groupings; Environmental Engineering, Environmental Science, and other Civil Engineering electives as listed below. Other graduate courses in the University may also be accepted with the approval of the program advisor. Electives do not have to be chosen from only one area.

Environmental Engineering

CIV	3301	Surface Water Hydrology and Contaminant Transport	4
CIV	3302	Groundwater Hydrology and Contaminant Transport	4
CIV	3303	Groundwater Modeling	4
CIV	3304	Advanced Wastewater Treatment and Industrial Waste Processes	4

Environmental Science

CIV	3305	Solid and Hazardous Waste Management Practices	4
CIV	3306	Air Pollution	4
CIV	3307	Environmental Protection and Management	4
CIV	3372	Air Sampling and Analysis	2

Other Civil Engineering Electives

CIV	3101	Applied Probability	4
CIV	3132	Engineering Statistics	2
CIV	3201	Construction Management	4
CIV	3202	Legal Aspects of Civil Engineering	4
CIV	3407	Engineering Geology	4

Geotechnical/Geoenvironmental Engineering

The Geotechnical Engineering program includes study in the areas of soil mechanics/foundations and geoenvironmental. Beginning with a core of required courses providing a basic geotechnical background for all students, each student is able to select courses from both of the two elective areas in order to concentrate their professional interest. Geotechnical engineering students are also encouraged to select courses offered in the structural engineering program. Each student must meet with his/her faculty advisor at the beginning of his/her program to select an appropriate sequence of courses.

Course Requirements	With Report	With Thesis
Required Core Courses	12 QH	12 QH
Master of Science Report or Thesis	4 QH	8 QH
Elective Courses	24 QH	20 QH
Minimum Quarter Hours Required*	40 QH	40 QH

* exclusive of any preparatory courses

Required Core Courses

			Credits
CIV	3302	Groundwater Hydrology and Contaminant Transport	4
CIV	3401	Advanced Soil Mechanics	4
CIV	3402	Advanced Foundation Engineering	4
		Master of Science Report CIV 3850	4
or		Master of Science Thesis CIV 3860	8

Soil Mechanics/Foundations Electives

CIV	3203	Construction Equipment and Modeling	4
CIV	3303	Groundwater Modeling	4
CIV	3403	Seepage and Stability	4
CIV	3404	Introduction to Dynamics and Earthquake Engineering	4
CIV	3405	Soil Dynamics	4
CIV	3406	Earthquake Engineering	4
CIV	3407	Engineering Geology	4

Geoenvironmental Engineering Electives

CIV	3301	Surface Water Hydrology and Contaminant Transport	4
CIV	3303	Groundwater Modeling	4
CIV	3305	Solid and Hazardous Waste Management Practices	4
CIV	3312	Environmental Chemistry	4

CIV	3321	Environmental Biological Processes	4
CIV	3327	Environmental Laboratory	4
CIV	3407	Engineering Geology	4

Additional Electives

CIV	3101	Applied Probability	4
CIV	3202	Legal Aspects of Civil Engineering	4
CIV	3501	Advanced Structural Analysis	4
CIV	3503	Structural Dynamics	4
MIM	3010	Numerical Methods in Mechanical Engineering	4
MIM	3690	The Finite Element Method	4

Structures

The Structures program includes courses in the areas of structural mechanics, structural analysis and design, dynamics of structures and earthquake engineering. Students pursuing a Masters in structural engineering can select, with their advisor, a course sequence with an analytical or design focus. Ph.D. students will obtain a strong background in theory as well as design.

Twenty-eight credit hours (24 in the Thesis option) must be taken from the list of core courses shown below. Other courses can be selected from any Civil Engineering graduate course offering. Each student must meet with his/her advisor in the first quarter of study to obtain advice and approval on a program that is best fitted to his/her interests and objectives.

Both the Master of Science and the Master of Science in Civil Engineering are awarded after the completion of 40 credit hours of work and satisfactory approval of the Masters Thesis or Masters Report. Satisfactory approval of the Masters Thesis requires an oral presentation.

Course Requirements	**With Report**	**With Thesis**
Core Courses	28 QH	24 QH
Master of Science Report or Thesis	4 QH	8 QH
Elective Courses **	8 QH	8 QH
Minimum Quarter Hours Required*	40 QH	40 QH

* exclusive of any preparatory courses

** These credits can also be selected from the list shown below

Core Course Selections			**Credits**
CIV	3101	Applied Probability	4
CIV	3401	Advanced Soil Mechanics	4
CIV	3402	Advanced Foundation Engineering	4
CIV	3404	Introduction to Dynamics and Earthquake Engineering	4
CIV	3405	Soil Dynamics	4
CIV	3406	Earthquake Engineering	4
CIV	3501	Advanced Structural Analysis	4
CIV	3502	Advanced Mechanics	4
CIV	3503	Structural Dynamics	4
CIV	3504	Seismic Analysis and Design	4
CIV	3505	Behavior of Reinforced Concrete Structures	4
CIV	3506	Behavior of Steel Structures	4

CIV	3507	Design of Pre-stressed Concrete Structures	4
CIV	3508	Advanced Materials	4
CIV	3509	Stability	4
Master of Science Report CIV 3850			4
or Master of Science Thesis CIV 3860			8

Other electives can be selected from the core elective list and from the following courses:

Analytical Orientation

MIM	3000	Mathematical Methods for Mechanical Engineers	4
MIM	3010	Numerical Methods in Mechanical Engineering	4
MIM	3625	Advanced Dynamics	4
MIM	3630	Vibration Theory and Applications	4
MIM	3690	The Finite Element Method	4

Design Orientation

MIM	3350	Computer Aided Graphics and Design	4
MIM	3665	Engineering Fracture Mechanics	4
MIM	3825	Electronic Behavior 1	4

Transportation Engineering

The Transportation Engineering Program is designed for students with career goals in transportation engineering and transportation planning. The program consists of a core of courses in transportation planning and engineering, supported by related courses in applied mathematics, engineering, economics, policy, and management.

Course Requirements	With Report	With Thesis
Required Core Courses	14 QH	14 QH
Restricted Electives	14 QH	10 QH
Other Electives	8 QH	8 QH
Master of Science Report or Thesis	4 QH	8 QH
Minimum Quarter Hours Required *	40 QH	40 QH

* exclusive of any preparatory courses

Required Core Courses **Credits**

CIV	3101*	Applied Probability	4
CIV	3132	Engineering Statistics	2
CIV	3642	Transportation Planning	4
MIM	3530	Operations Research 1	4

* students without a preparatory course in probability may take MIM 3400 (4QH) instead

Restricted Electives

CIV	3602	Transportation Demand Models	4
CIV	3603	Transportation Supply Models	4
CIV	3607	Traffic Engineering	4

CIV	3610	Urban Public Transportation	2
ECN	3366	Economics of Transportation	3
MIM	3503	Simulation Methodology and Applications	4
MIM	3513	Network Analysis and Adv. Linear Programming	4
MIM	3515	Queuing Theory	4
MIM	3531	Operations Research 2	4
POL	xxxx	Advisor-approved course in transportation policy	

Other Electives

CIV	xxxx	Any CIV course	
MIM	xxxx	Courses in engineering management, information systems, or mathematical methods	
ECN	3220	Microeconomic Theory	4
ECN	3363	Urban Economic Theory	3
ECN	3241	Econometrics	4
TRN	3903	Corporate Logistics Management	3
XXX	xxxx	Any advisor-approved course, excluding preparatory courses	

THE DOCTOR OF PHILOSOPHY DEGREE

Award of the Doctor of Philosophy degree is based on exceptional performance in course work and evidence of ability to formulate and execute original research. The degree program has two components: (1) An academic program consisting of a set of graduate level courses which provide depth in a specific area of Civil Engineering (the major field) and additional exposure, at an advanced level, to one or more science disciplines (the minor field); and (2) the doctoral dissertation, an extended independent research effort on a relevant technical problem resulting in an original contribution.

Mastery of the subject matter is measured by a qualifying examination covering a subset of subjects selected from the major field. Research progress is monitored periodically by a Doctoral Dissertation Committee and the candidate is required to present and defend the research results before an expanded group of faculty and research staff at the completion of the work.

The doctoral program is deliberately designed to be flexible with respect to subject area since the PhD degree is primarily a "research" degree and therefore the program must be adaptable to changes in research needs.

Qualifying Examination and Degree Candidacy

The qualifying examination will consist of written and oral portions and its content will depend on the educational background and objectives of the student. In general, the written part will cover subject matter at the Master's level selected from the major field and will include: (1) basic engineering and science disciplines and (2) civil engineering application areas. The oral portion will measure general comprehension and aptitude for research. If the examination is failed, it may be repeated with permission of the PhD Committee. The qualifying examination must be taken no later than two years after admittance as a doctoral student. Upon successful completion of the examination and satisfaction of the general graduate school regulations, the student is classified as a doctoral candidate. Doctoral study must be completed within five years after classification as a doctoral degree candidate.

Course Requirements

A proposal defining the content of the academic program is developed jointly by the student and faculty advisor and then reviewed by the PhD Committee. Intellectual rigor, connectivity of subject matter, and compatibility with departmental interests are critical issues. Final approval is arrived at through discussion and represents a mutual agreement between the student and the PhD Committee. Flexibility in program definition is encouraged, especially in areas where complementary courses exist in other departments, or where expertise resides outside the Department and the objective is to introduce new technology in civil engineering practice.

The academic program must contain at least 72 quarter hours of graduate level course work. Not more than 4 QH of CIV 3835 *Special Project in Civil Engineering* can be counted toward the PhD program. A minimum of 60 quarter hours must be related to the major field but can include courses from other departments when appropriate. The minor field must include a minimum of 12 quarter hours of course work in science disciplines of interest to civil engineers, e.g., mathematics, computer science, materials science, earth sciences, chemistry, biology, health sciences. Upon successful completion of the PhD qualifying examination and the majority of required course work, the student is required to register in three consecutive quarters for CIV 3880 (PhD Thesis). Upon completion of this sequence, the student is required to register for CIV 3799 (PhD Continuation) in every quarter until the dissertation has been completed. Students may not register for continuation until the three-quarter thesis sequence has been fulfilled.

Students with a MS degree will receive 36 QH of credit toward the PhD program. A minimum of 28 QH of course work beyond the MS degree must be completed at Northeastern.

Language Requirement

The candidate must be proficient in technical writing and oral presentation in the English language. Appropriate course work may be required by the PhD Committee.

Residence Requirement

Three successive quarters of full-time study on campus are required to establish residence. The total effort for a doctorate involves, as a minimum, three years of full-time work beyond the Bachelor's Degree. Candidates who enter the doctoral program with a Master of Science Degree may complete the requirements in less time, but they should anticipate at least two years of full-time effort.

Dissertation

Once degree candidacy has been established, the student is allowed to proceed with the dissertation effort. The candidate is required to generate a dissertation proposal and identify a civil engineering faculty member who will act as the dissertation advisor. A Dissertation Committee, consisting of the dissertation advisor and at least four other Northeastern faculty members, selected by the PhD Committee, will monitor progress and approve the final document.

Comprehensive Examination

The comprehensive examination consists of a defense of the doctoral research work and an examination on subject matter related to the dissertation area.

FACULTY

Mishac K. Yegian, Chairman

Professors

Blanc, Frederic C., PhD, PE, New York University; wastewater, industrial, hazardous, and solid waste

Cochrane, John J., PhD, PE, Rensselaer Polytechnic Institute; treatment process design, computer-aided analysis and design, water quality management

Gregory, Constantine J., PhD, Rutgers University; air pollution control, environmental modeling, industrial hygiene

King, Paul H., PhD, PE, Stanford University; water quality management, water treatment, chemical treatment of industrial wastewater

Yegian, Mishac K., PhD, PE, Massachusetts Institute of Technology; soil dynamics, earthquake engineering, risk analysis, geotechnical engineering, geosynthetics, seismic response of waste containments

Associate Professors

Bernal, Dionisio, PhD, University of Tennessee; earthquake engineering, structural engineering

Furth, Peter G., PhD, Massachusetts Institute of Technology; transportation analysis and planning, optimization, applied probability and statistics

Scranton, Richard J., MS, Massachusetts Institute of Technology; transportation systems, mechanics, applied probability

Sheahan, Thomas C., ScD, PE, Massachusetts Institute of Technology; geotechnical engineering, clay behavior, laboratory equipment automation, and measurement instrumentation

Touran, Ali, PhD, PE, Stanford University; construction engineering and management

Wei, Irvine W., PhD, Harvard University; water chemistry, treatment processes, acid precipitation

Assistant Professors

Alshawabkeh, Akram N., PhD, Louisiana State University; geotechnical and geoenvironmental engineering, soil remediation, electrokinetic processing, contaminant fate and transport, numerical modeling

Miralles-Wilhelm, Fernando, PhD, PE, Massachusetts Institute of Technology; groundwater hydrology and contaminant transport, modeling of geotechnical and microbiological processes in subsurface environments

Oluokun, Francis A., PhD, University of Tennessee; structural design and behavior, anchorage to concrete, fiber reinforced concrete, precast prestressed concrete

Wadia-Fascetti, Sara, PhD, Stanford University; structural engineering, structural dynamics, applications to infrastructure and deteriorating structures, earthquake ground motion, uncertainties in structural modeling and analysis

PROGRAM ADVISORS

	Part-time		Full-time	
Construction	(A-Z)	Prof. Touran	(A-Z)	Prof. Touran
Environmental	(A-M)	Prof. Gregory	(A-M)	Prof. Gregory

	Part-time		Full-time	
Environmental	(N-Z)	Prof. Wei	(N-Z)	Prof. Wei
Geotechnical	(A-Z)	Prof. Yegian	(A-Z)	Prof. Yegian
Structural	(A-Z)	Prof. Wadia-Fascetti	(A-Z)	Prof. Bernal
Transportation	(A-Z)	Prof. Furth	(A-Z)	Prof. Furth

COURSE DESCRIPTIONS

Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering sheets to determine what courses are actually offered in any given quarter and at what day and time.

CIV 3101 Applied Probability (4 QH)
Fall Quarter
(Replaces CIV 3131)
Review of fundamental probability concepts, including conditional probability , expectation, and covariance. Probability distributions commonly used in Civil Engineering. Simple reliability models. Derived distributions. Maximum Likelihood Estimation. Sampling distributions. Confidence intervals and hypothesis testing. Goodness of fit. Focus is on modeling applications in Civil Engineering. *Prep. Undergraduate course in probability, or permission of instructor.*

CIV 3132 Engineering Statistics (2 QH)
Winter Quarter, Alternate years
Sampling techniques, including stratified sampling, two-stage sampling, and ratio estimation. Linear regression. Focus is on statistical applications in Civil Engineering. *Prep. CIV 3101, MIM 3400, or undergraduate course in probability with permission of instructor.*

CIV 3201 Construction Management (4 QH)
Fall Quarter
(Replaces CIV 3231 and CIV 3232)
A presentation of all aspects of Construction Management; industry profile, parties involved, contracts, bonds, bidding, changes, preplanning, CM approach and partnering. Another area of emphasis is planning and scheduling, network-based scheduling systems (CPM), resource management, network acceleration, PERT probabilistic approach, WBS and work packaging. Students will use a software package as part of the requirements. *Prep. Admission to Graduate School of Engineering.*

CIV 3202 Legal Aspects of Civil Engineering (4 QH)
Spring Quarter
(Replaces CIV 3241 and CIV 3242)
A presentation of U.S. and International legal systems and theories necessary for the comprehension of business and contractual liabilities, rights and obligations in the engineering field. Description and evaluation of various types of construction contracts, procedures and formats for submitting bids, filing claims, and legal steps to avoid liabilities. *Prep. Admission to Graduate School of Engineering.*

CIV 3203 Construction Equipment and Modeling (4 QH)
Winter Quarter
(Replaces CIV 3237 and CIV 3238)
Selection and application of construction equipment; earth-moving equipment including excavators, bulldozers, scrapers, *etc.*; belt-conveyor systems, bituminous pavements material and equipment. Productivity analysis of equipment operations, equipment economics, computer modeling of equipment production systems including truck-loader, scraper-tractor; simulation of construction operations. Students will use a software package for simulation. *Prep. CIV 3101 or CIV 3132.*

CIV 3245 Construction Seminar (2QH)
Spring Quarter
A reading and discussion course centering on recent research publications in Construction Engineering. *Prep. Limited to Construction Management Program majors.*

CIV 3252 Construction Project Control and Organization (2QH)
Winter Quarter
Organization of construction firms, both at the general corporate level and at the project level. Organization dynamics designed to respond to the requirements of the environment given the internal constraints of the firm. Computer systems for the control of construction projects. Design attributes to fit the needs of the organization and the end users. Estimating, scheduling, budgeting and financial control of projects. Network-based systems for planning and time control. Intra-project and inter-project resource allocation. Database design concepts for decision support systems. *Prep. CIV 3201.*

CIV 3301 Surface Water Hydrology and Contaminant Transport (4 QH)
Fall Quarter
(Replaces CIV 3348 and CIV 3355)
Analysis of hydrologic processes for selected engineering applications. Topics include: hydrographic analysis, rainfall-runoff, routing, urban hydrology, storage analysis, hydrologic design. Effects of pollutant discharges into surface water bodies, principles of water quality modeling in lakes, rivers and coastal areas, mixing in estuaries and embayments, models of reservoirs and ponds, stratification in lakes and reservoirs, sediment transport, nutrient cycling and eutrophication, case studies. *Prep. Admission to the Graduate School of Engineering, CIV 1320 (Hydraulic Engineering).*

CIV 3302 Groundwater Hydrology and Contaminant Transport (4 QH)
Winter Quarter
(Replaces CIV 3358)
Covers the fundamentals of the flow of groundwater and its importance as a water resource. Topics include: porous media characteristics, Darcy's equation, non-linear resistance, the groundwater flow equations, spatial averaging simplifications, aquifer storage and transmissivity, transient flow in aquifers, well hydraulics, pump test analysis. Contaminant transport in groundwater, advection and dispersion, reactive transport. Multiple phase flow, unsaturated flow and transport. *Prep. Admission to the Graduate School of Engineering, CIV 1320 (Hydraulic Engineering).*

CIV 3303 Groundwater Modeling (4 QH)
Spring Quarter
(Replaces CIV 3360 and CIV 3362)
Computational modeling of groundwater flow and contaminant transport. Topics include: mass balance equations, fluxes and reactive transport, conceptual models. Groundwater flow modeling. Finite difference and finite element methods. Numerical modeling of contaminant transport. Data requirements, implementation of singularities in flow and transport, calibration targets, sensitivity analyses, limitations of models, public domain codes, case studies. Students must be familiarized with numerical solutions to systems of algebraic equations. *Prep. CIV 3302.*

CIV 3304 Advanced Wastewater Treatment and Industrial Waste Processes (4 QH)
Spring Quarter
(Replaces CIV 3317 and CIV 3341)
An examination of industrial waste problems with design considerations for industrial solids and liquid wastes is combined with unit operations and processes used for advanced wastewater treatment systems design. Representative topics included are: industrial waste characterization, industrial waste survey techniques, residuals management, nitrification, biological nutrient removal, chemical treatment technologies, land treatment, waste reduction, membrane technologies and recycle or reuse of liquid and solid streams. *Prep. CIV 3318.*

CIV 3305 Solid and Hazardous Waste Management Practices (4 QH)
Winter Quarter
(Replaces CIV 3384 and CIV 3386)
Integrated solid waste management for engineering and science students combined with the principles of hazardous waste management and site remediation technology. Topic areas include: waste generation, waste properties, waste classification, collection systems, transformation, recycling, thermal conversion, landfilling, and site remediation technologies such as bioremediation, air stripping, and vapor extraction. *Prep. CIV 3318.*

CIV 3306 Air Pollution (4 QH)
Winter Quarter
(Replaces CIV 3370 and CIV 3374)
Theory and practice related to engineering management of air resources, applications of models for atmospheric dispersion of pollutants; analysis of control systems for gaseous and particulate emissions utilizing dry collection, wet collection, absorption and catalytic processes. Discussion of source control and air quality standards. Part of the course focuses on biological and chemical aspects of air pollution with emphasis on toxicological aspects, physiological effects of aerosols, analysis of organic and inorganic

constituents of the atmosphere and rational for establishing air quality criteria and standards. *Prep. Admission to Graduate School.*

CIV 3307 Environmental Protection and Management (4 QH)
Spring Quarter
(Replaces CIV 3380)
Current environmental problems are analyzed through use of case studies, role-playing and computer simulation. Topics illustrate management of specific environmental systems such as solid and hazardous waste facilities, wastewater treatment, incineration and septic systems. A broad range of environmental issues are included, ranging resource management to aspects of thermal and noise pollution. *Prep. Admission to Graduate School of Engineering.*

CIV 3312 Environmental Chemistry (4 QH)
Fall Quarter
A review of chemistry with applications to environmental engineering including: properties of water and pollutants, acid-base reactions, pH, alkalinity, equilibrium chemistry, chemical kinetics, chemical thermodynamics, coordination chemistry, precipitation-dissolution reactions, surface chemistry, adsorption-desorption, redox reactions and organic chemistry as it relates to the environment. *Prep. Two quarters of general chemistry.*

CIV 3318 Water and Wastewater Treatment (4 QH)
Fall and Winter Quarters
Design principles and theory of removal of impurities from water are covered. Treatment unit operations and processes typically include: packed tower aeration, screening, coagulation and flocculation, sedimentation, filtration, ion exchange, activated carbon adsorption and disinfection. Wastewater treatment with emphasis on secondary municipal treatment processes is covered including: preliminary treatment, primary clarification, activated sludge systems, aerated lagoons, aeration and mixing theory, fixed film biological treatment systems, anaerobic treatment systems and wastewater reuse. *Prep. Undergraduate fluid mechanics, CIV 3321 should be taken before or concurrently.*

CIV 3321 Environmental Biological Processes (4 QH)
Winter Quarter
A study of microbiology with emphasis on biological importance in environmental engineering applications. Includes: cell structure, cell nutrition, cell chemistry, morphology, aerobic and anaerobic microbial metabolism, major metabolic pathways, biological wastewater process theory and kinetics, nitrification, denitrification, pathogens, and effects of environment on microbial populations. *Prep. CIV 3312.*

CIV 3325 Environmental Chemistry Laboratory (2 QH)
Winter Quarter
A laboratory course emphasizing analysis related to important topics in environmental chemistry including acid-base reactions, chemical kinetics, precipitation reaction, coordination chemistry, and oxidation-reduction reactions. Analytical techniques include colorimetry, gravimetric and electrochemical methods, atomic absorption spectrophotometry, and gas chromatography. *Prep. CIV 3312.*

CIV 3326 Biological Processes Laboratory (2 QH)
Spring Quarter
A laboratory course emphasizing analysis related to microbiological examination and other treatment parameters used to monitor the biological process such as: BOD, TOC, COD, gravimetric methods and dissolved oxygen. Enzyme kinetics and evaluation of kinetic coefficients for biotreatment will be covered. *Prep. CIV 3321 and CIV 3325.*

CIV 3327 Environmental Laboratory (4 QH)
Fall Quarter
Embodies the material in CIV 3325 and CIV 3326. *Prep. CIV 3312 (or to be taken concurrently with CIV 3312) and CIV 3321.*

CIV 3332 Environmental Computer Applications (2 QH)
Fall Quarter
Fundamental principles of deterministic and stochastic modeling applied to environmental problems. Utilization of mathematical software for the development of computer models and simulation related to treatment plant performance, stream and lake modeling and contaminant dispersion in air, water, and soil. *Prep. Admission to Graduate School of Engineering.*

CIV 3372 Air Sampling And Analysis (2 QH)
Fall Quarter
Basic design considerations and requirements for air quality surveillance. Examination of the methodologies for air quality sampling, sampling frequencies, measurement techniques and data acquisition, handling and analysis. Manual and automated techniques are discussed for the evaluation of source and ambient systems. Statistical techniques are employed to evaluate air quality management strategies. *Prep. CIV 3306.*

CIV 3401 Advanced Soil Mechanics (4 QH)
Fall Quarter
(Replaces CIV 3410 and CIV 3411)
Characterization of soils, soil mineralogy and chemistry, stresses within a soil mass, basic porous media flow principles, effective stress principle, compaction, drained and undrained stress-strain-strength concepts, consolidation theory and its applications. *Prep. Admission to Graduate School of Engineering, or permission of instructor.*

CIV 3402 Advanced Foundation Engineering (4 QH)
Winter Quarter
(Replaces CIV 3420 and CIV 3421)
Bearing capacity and settlement analysis of conventional shallow foundations and combined footings; mat design; lateral earth pressure theory and application to retaining wall design; braced excavations, sheet pile wall design, slurry trench walls; bearing capacity design and analysis for deep foundations; laterally loaded piles, friction piles, and pile driving analysis. *Prep. CIV 3401.*

CIV 3403 Seepage and Stability (4 QH)
Spring Quarter, Alternate years
(Replaces CIV 3412)
Analysis of seepage, confined and unconfined flow. Finite element method, computer applications. Drained and undrained behavior of soils, and long-term and short-term effects on shear stress-strain-strength. Slope and embankment stability analysis with computer applications. Embankments on soft clays. *Prep. CIV 3401.*

CIV 3404 Introduction to Dynamics and Earthquake Engineering (4 QH)
Fall Quarter
(Replaces CIV 3470)
Dynamic forces in Civil Engineering; ground vibrations, blast vibrations. Dynamics of single-degree-of-freedom systems, seismicity, earthquake ground vibrations, response spectrum, wave propagation, site effects on ground motion, design response spectra. *Prep. Admission to Graduate School of Engineering.*

CIV 3405 Soil Dynamics (4 QH)
Winter Quarter, Alternate years
(Replaces CIV 3471)
Dynamics of single mass, multi-degree-of-freedom systems. Design of foundations for dynamic loads. Dynamics soil properties; laboratory and field measurements, liquefaction. *Prep. CIV 3404.*

CIV 3406 Earthquake Engineering (4 QH)
Spring Quarter, Alternate years
(Replaces CIV 3485)
Seismic sources, ground motion attenuation, seismic hazard analysis, design ground motions, soil-structure interaction, structural response, seismic design of buildings, earth retaining structures, earth dams and landfills. *Prep. CIV 3404.*

CIV 3407 Engineering Geology (4 QH)
Spring Quarter, Alternate years
(Replaces CIV 3450)
Selected topics in historical and structural geology related to engineering geology; origin and occurrence of various rock types, geologic structures, faulting and joint systems; weathering of rock and weathering products, glaciation, geologic mapping and environmental aspects; case studies. *Prep. Undergraduate course in geology.*

CIV 3501 Advanced Structural Analysis (4QH)
Fall Quarter
(Replaces CIV 3536)
Formulation and solution of structural problems with primary application to member systems (trusses, frames, curved members), matrix formulation of flexibility and stiffness methods, geometrically nonlinear behavior, static condensation, substructuring, multiple structural systems, introduction to energy methods. *Prep. Admission to the Graduate School of Engineering.*

CIV 3502 Advanced Mechanics (4QH)
Spring Quarter
(Replaces CIV 3510)
Analysis of force equilibrium (stress), deformation/displacement (strain), and force/deformation (Hooke's Law) for an elastic solid; compatibility; governing equations for complete and approximate elasticity solution. Plane stress solution for narrow rectangular beams. Torsion, Saint Venant's theory, membrane analogy, rectangular sections, thin open and closed sections. Introduction to bending of thin plates. *Prep. Admission to the Graduate School of Engineering.*

CIV 3503 Structural Dynamics (4QH)
Winter Quarter
(Replaces CIV 3546)
Solution techniques for linear SDOF systems: convolution, analysis in the frequency domain, numerical integration, relationship between time and frequency domain procedures. Nonlinear SDOF systems.

Formulation of equations of motion for discrete multi-degree-of-freedom linear systems. Generation of mass, stiffness and damping matrices, static condensation. Calculation of mode shapes and natural frequencies. Analysis of linear response in mode shapes and natural frequencies. Analysis of linear response in modal coordinates. Direct integration of equations of motion. The response spectrum method in modal analysis. *Prep. CIV 3501 and CIV 3502 .*

CIV 3504 Seismic Analysis and Design (4QH)
Spring Quarter, Alternate years
(Replaces CIV 3480)
Formulation of equations of motion for multi-support excitation. Soil-Structure Interaction. Torsional response. Inelastic response spectra. Computation of inelastic response in MDOF systems. Dynamic Instability. Earthquake considerations in building design. Seismic code provisions. *Prep. CIV 3404 and CIV 3503.*

CIV 3505 Behavior of Reinforced Concrete Structures (4QH)
Fall Quarter, Alternate years
(Replaces CIV 3559 and CIV 3561)
Moment-curvature relationships for reinforced concrete cross sections; effect of design parameters in resulting behavior; ductility; moment-curvature and load-deflection relationships for reinforced concrete beams; effective stiffness, combined bending and axial load, shear and axial load, shear and torsion. Relation between research results and specifications for design. *Prep. Undergraduate Concrete Design.*

CIV 3506 Behavior of Steel Structures (4QH)
Fall Quarter, Alternate years
(Replaces CIV 3570)
Behavior of structural steel members due to static and fatigue loading, simple shear and moment connections for beams; composite columns and beam columns, development of column strength curves; buckling about weak and strong axes. Slender compression elements; brittle fracture; torsion. *Prep. Undergraduate Steel Design.*

CIV 3507 Design of Pre-stressed Concrete Structures (4QH)
Winter Quarter, Alternate years
(Replaces CIV 3560)
Properties of pre-stressing materials; methods of pretensioning and posttensioning; prestress losses; analysis and design of simple and continuous beams and slabs for flexure and shear, camber, deflection and crack control, prestressed column design, load balancing method for analysis of indeterminate prestressed structure. Behavior of prestressed concrete beams and columns. *Prep. Undergraduate Concrete Design.*

CIV 3508 Advanced Materials (4QH)
Winter Quarter, Alternate years
(Replaces CIV 3520)
Concrete components and microstructure including: chemical, physical, and micro-structural properties of cement hydration; role of water, effect of water quality and sulfate attack; aggregate type and properties, possible problems with aggregates (including alkali-aggregate reaction). Behavior of hardened concrete including: factors affecting concrete strength; effects of temperature, creep and shrinkage; non-structural cracking, curing of hardened concrete; corrosion of steel in concrete, durability. Special Portland and non-Portland cements, admixtures, special concretes. *Prep. Undergraduate Civil Engineering Materials.*

CIV 3509 Stability (4QH)
Spring Quarter, Alternate years
(Replaces CIV 3525)
Elastic stability of columns. Principle of minimum potential energy. Buckling analysis of rigid frames. Second order analysis of frames using stability functions. Numerical methods in stability. *Prep. CIV 3501.*

CIV 3602 Transportation Demand Models (4 QH)
Winter Quarter, Alternate years
(Replaces CIV 3650)
Trip generation models, including cross-classification and regression models. Trip distribution models, including gravity models and various methods of matrix estimation. Mode choice models, including logit models, nested logit, and incremental prediction. Elasticity and direct demand models. *Prep. CIV 3101 or MIM 3400, CIV 3642.*

CIV 3603 Transportation Supply Models (4 QH)
Spring Quarter, Alternate years
(Replaces CIV 3651)
Important models of transportation system performance and transportation system design. Delay models for intersections and freeways. Shortest path models. Traffic assignment models, including equilibrium assignment. Traffic signal timing algorithms. Supporting non-linear optimization methods including interval reduction, convex combinations, Kuhn-Tucker conditions, and dynamic programming. *Prep. Multivariate calculus.*

CIV 3607 Traffic Engineering (4 QH)
Spring Quarter
(Replaces CIV 3630)
Traffic flow theory and measurement. Capacity and level of service analysis for intersections, arterials, and highways. Intersection design. Traffic analysis and design software. Transportation systems management. *Prep. Admission to Graduate School of Engineering.*

CIV 3610 Urban Public Transportation (2 QH)
Spring Quarter
Analysis and planning of public transportation systems, including bus, subway, commuter rail, and paratransit. Performance models; service evaluation and monitoring; data collection; service design; demand prediction; institutional and economic issues. *Prep. CIV 3101, or MIM 3400.*

CIV 3642 Transportation Planning (4 QH)
Fall Quarter, Alternate Years
Introduction to transportation planning for both the short term and long term. Travel demand forecasting, including trip generation, trip distribution, modal split, and network assignment. Demand elasticity. Transit route scheduling. Alternatives evaluation, including environmental impact, economic comparison, and financial impact. *Prep. Undergraduate Calculus.*

CIV 3798 Master's Continuation (0QH)
Any Quarter

CIV 3799 PhD Continuation (0QH)
Any Quarter

CIV 3830 Special Topic in Civil Engineering (2QH)
Fall, Winter, Spring Quarters
This course is offered when the need for a special topic is evident to faculty and students. The course is initiated by the appropriate faculty members and discipline committee and approved by the department. *Prep. Permission of the instructor.*

CIV 3835 Special Project in Civil Engineering (2QH)
Any Quarter
An individual effort in an area selected by student and advisor and approved by the Departmental Discipline Committee resulting in a definitive report. *Prep. Permission of the Department.*

CIV 3850 Master's Report (4QH)
Any Quarter
An individual effort consisting of laboratory and/or literature investigation and analysis or advanced design of a project in an area of civil engineering selected by student and advisor resulting in a definitive report. The report must be completed 7 years from the start of the Master's program. *Prep. Permission of the Department.*

CIV 3851 Master's Report (2QH)
Any Quarter

CIV 3860 Master's Thesis (8QH)
Any Quarter
Analytical and/or experimental research conducted by arrangement with and under the supervision of the department. *Prep. Permission of the Department.*

CIV 3861 Master's Thesis (4QH)
Any Quarter

CIV 3862 Master's Thesis (2QH)
Any Quarter

CIV 3880 PhD Thesis (0QH)
Any Quarter
Open to full-time Doctoral students only. *Prep. Admission to doctoral program in Civil Engineering.*

Computer Systems Engineering

The Graduate School of Engineering offers an interdisciplinary program leading to the degree of Master of Science in Computer Systems Engineering. This program has courses drawn from the Department of Electrical and Computer Engineering, the Department of Mechanical, Industrial and Manufacturing Engineering and the College of Computer Science.

The program may be pursued on a full-time, part-time or cooperative plan basis. Students may select courses from both the day and evening offerings. Students must select one of the following areas of concentration within the program:

Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM)
Engineering Software Design

Students admitted into this program are assigned a faculty advisor depending upon the area of concentration selected.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of forty-eight quarter hours of graduate courses with a minimum grade point average of 3.00 is required to receive the degree. Refer to the regulations in this catalogue for detailed information on academic and administrative policies.

Students holding an engineering degree from an ABET accredited institution will qualify to apply for the Master of Science in Computer Systems Engineering. Students with a Bachelor of Science in the physical sciences may also apply. A Graduate Record Examination (GRE) may be required.

Prerequisite Courses

Students are expected to be proficient in the C programming language. Other prerequisites may be required of students in each concentration area. The following prerequisites are required, and up to 4 quarter hours of these courses may be applied to the 48 quarter hour minimum degree requirement. Determination of prerequisite needs will be made at the time of admission.

Prerequisite	Required by
High-level structured language	All concentrations
MIM 3104 Data Structures	All concentrations
MIM 3140 JAVA	All concentrations

Course Descriptions

See the respective department section of this catalogue for course descriptions.

Course Requirements

Each area of concentration requires a total of 48 quarter hours of course work consisting of the required courses plus electives selected from the approved elective lists. Other courses may be used as electives if approved by petition. Students should petition through their academic advisor.

CAD/CAM

Required Core Courses				Credits
	MIM	3104	Data Structures	4
	MIM	3128	Database Management Systems	4
or	COM	3315	Database Systems	4
	MIM	3325	Robot Mechanics and Control	4
	MIM	3350	Computer-Aided Graphics and Design	4
	MIM	3300	Manufacturing, Design and Computers	4

Subject Area Elective Courses

Students may select courses from the required list of the Engineering Software Design option. Full-time students are encouraged to complete a thesis for twelve quarter hours of credit. In addition, the following courses may be taken as electives. Any other elective outside of the following list must be pre-approved by petition.

Design Electives				Credits
	MIM	3000	Mathematical Methods for Mechanical Engineering	4
	MIM	3010	Numerical Methods in Mechanical Engineering	4
	MIM	3600	Theory of Elasticity	4
	MIM	3625	Advanced Dynamics	4
	MIM	3630	Vibration Theory and Applications	4
	MIM	3675	Advanced Mechanics of Materials	4
	MIM	3690	The Finite Element Method	4
	MIM	3695	Experimental Techniques in Design	4

Manufacturing Electives			
ECE	3463	Robot Vision and Sensors	4
ECE	3466	Robotics and Automation Systems	4
ECE	3472	Special Topics in Robotics	4
MIM	3025	Human Factors Engineering	4
MIM	3217	Engineering Project Management	4
MIM	3305	Manufacturing Methods and Processes	4
MIM	3310	Computer Methods in Manufacturing	4
MIM	3375	Computer-Aided Manufacturing	4
MIM	3400	Basic Probability and Statistics	4
MIM	3416	Statistical Quality Control	4
MIM	3440	Total Quality Control for Engineering	4
MIM	3503	Simulation Methodology and Applications	4

MIM	3530	Operations Research 1	4

Intelligent CAD/CAM Electives

CHE	3510	Modeling and Simulation of Chemical Processes	4
COM	3112	LISP Lab	2
COM	3315	Database Systems	4
COM	3360	Adaptive Object-Oriented Software Development	4
COM	3410	Artificial Intelligence Problem Solving	4
COM	3411	Knowledge Based Systems	4
COM	3420	Knowledge Representation	4
COM	3430	Expert Systems	4
COM	3440	Natural Language Processing	4
COM	3480	Machine Learning and Neural Networks	4
COM	3499	Topics in Artificial Intelligence	4
ECE	3221	Linear Systems Analysis	4
MIM	3124	Software Engineering	4
MIM	3129	Expert Systems in Engineering	4
MIM	3130	Machine Intelligence	4
MIM	3131	Machine Learning	4
MIM	3137	Programming Languages for Software Engineering	4
MIM	3140	Java with Engineering Applications	4
MIM	3141	Advanced Java Development	4

Engineering Software Design

Required Core Courses **Credits**

	MIM	3107	Operating Systems & Systems Software	4
	MIM	3110	Computer Architecture	4
	MIM	3124	Software Engineering	4
	MIM	3141	Advanced Java Development	4
	MIM	3152, 3153	Software Engineering Project 1, 2	4 each
or	MIM	3935	Master's Thesis	8
	MIM	3217	Engineering Project Management	4

Subject Area Elective Courses

Students may select courses from the required list of the CAD/CAM option, except for those that also appear as Engineering Software Design prerequisite courses. In addition, the following courses may be taken as electives:

Software Engineering Electives **Credits**

MIM	3030	Human-Computer Interaction	4
MIM	3125	Software Development and Evolution	4
MIM	3126	Networks and Telecommunications	4
MIM	3128	Data Base Management Systems	4
MIM	3129	Expert Systems in Engineering	4
MIM	3130	Machine Intelligence	4

MIM	3131	Machine Learning	4
MIM	3133	C++ Object-Oriented Design	4
MIM	3140	JAVA with Engineering Applications	4
MIM	3300	Manufacturing, Design and Computers	4
MIM	3310	Computer Methods in Manufacturing	4
MIM	3325	Robot Mechanics and Control	4
MIM	3350	Computer-Aided Graphics and Design	4
MIM	3375	Computer-Aided Manufacturing	4
MIM	3503	Simulation Methodology & Applications	4
MIM	3505	Advanced Simulation Analysis	4
MIM	3522	Systems Engineering Design and Analysis	4
ECE	3321	Digital Signal Processing	4
ECE	3463	Robot Vision and Sensors	4
ECE	3466	Robotics and Automation Systems	4
ECE	3556	Special Topics in System Theory	4
COM	3355	Compiler Design	4
COM	3371	Digital Image Processing	4
COM	3420	Knowledge Representation and Inferencing	4
COM	3470	Computer Vision	4

THE DOCTOR OF PHILOSOPHY DEGREE

Students interested in pursuing research related to Computer Systems Engineering beyond the Master of Science level may pursue the Doctor of Philosophy degree under the Interdisciplinary Ph.D. program described elsewhere in this catalogue.

PROGRAM ADVISORS

Computer Systems Engineering (CAD/CAM)	Prof. I. Zeid
Computer Systems Engineering (Engineering Software Design)	Prof. R. Mourant

Department of Electrical and Computer Engineering

The Department of Electrical and Computer Engineering offers graduate programs leading to the degrees of Master of Science in Electrical Engineering, Master of Science (without specification), and Doctor of Philosophy in Electrical Engineering. The Master of Science degree program may be completed on either a part-time, a continuous full-time, or a cooperative full-time basis. The Ph.D. degree program must be completed on a basis consistent with the residence requirements for the degree. The curriculum offers areas of concentration in communications and signal processing; computer engineering; control systems and signal processing; electromagnetics, plasma and optics; electronic circuits and semiconductor devices; and power systems.

Students in the Industrial Fellowship or Women in Information Systems programs follow the same degree requirements in their subject areas required of all graduate students. Courses offered in the day typically carry four quarter hours of credit; their two-quarter-hour equivalents are given in the evening over two academic quarters.* Each full-time student is responsible for meeting with his or her faculty advisor early in the program so that an appropriate sequence of courses may be arranged. Part-time students should follow the prescribed requirements and confer with their faculty advisors as needed.

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of forty-four quarter hours of graduate courses with a minimum grade point average of 3.0 is required in all programs. Full-time students are required to complete either an eight quarter hour Master of Science thesis or a four quarter hour project as part of their program. Research Assistants and Industrial Fellowship students are required to complete a Master of Science thesis. Master of Science Thesis or Project is optional for part-time students. For students selecting the thesis option, an Examination Committee shall be formed consisting of the student's thesis advisor and two full-time faculty members (or one full-time faculty member and one advisor from industry) with background relevant to the thesis topic. The thesis shall be presented by the student to the Committee and to the ECE Department-at-large in the form of a seminar before final approval of the thesis is granted. For students selecting the Master of Science Project option, the student shall select one advisor, who will be responsible for the grade, and one other ECE faculty member. The project shall result in a written report and a final examination consisting of a poster session followed by 5-minute presentations. The M.S. Projects will be presented at one poster session scheduled the

* **NOTE**: to earn credit for a part A/part B course you must take both part A and part B.

Friday before final exam week. The results of the project should be of a quality that is suitable for publication or presentation at a professional conference. Please refer to the regulations of the Graduate School of Engineering for detailed information on academic and administrative policies.

All graduate courses presuppose mastery of the subject matter of a modern ABET accredited undergraduate curriculum in electrical engineering. Students with a Bachelor of Science degree in other engineering or related science fields and students with a BSEE degree who have not taken graduate academic work for some time may be required to take one or more of the following undergraduate level prerequisite courses to satisfy any deficiencies. These courses carry no credit toward the graduate degree.

Prerequisite Courses
(these courses cannot be used toward the 44 quarter hour degree requirement)

			Credits
ECE	3100	Introduction to Circuits and Systems	4
ECE	3101	Introduction to Electronics	4
ECE	3102	Introduction to Electromagnetic Field Theory	4
ECE	3103	Introduction to Digital Systems Design	4
ECE	3104	Introduction to Communications	4
ECE	3108	Introduction to Signals and Systems	4
ECE	3109	Introduction to Computer Systems	4
ECE	3120	Power Circuit Analysis 1	2
ECE	3130	Electrical Machinery Theory 1	2

Communications and Signal Processing

Course Requirements	Full-time with Thesis	Full-time with Project	Part-time Study
Required Core Courses	8 QH	8 QH	8 QH
Subject Area Required Courses	16 QH	16 QH	16 QH
Subject Area Elective Courses	12 QH	16 QH	20 QH
Master of Science Thesis or Project	8 QH	4 QH	0 QH
Minimum Quarter Hours Required*	44 QH	44 QH	44 QH

* exclusive of any prerequisite courses

Required Core Courses (2 QH equivalents are in parentheses)

			Credits
ECE	3211	(3212,3213) Math. Methods in Electrical Engineering 1	4
ECE	3241	(3242,3243) Applied Probability and Stochastic Processes	4

Subject Area Required Courses

ECE	3221	(3222,3223) Linear Systems Analysis	4
ECE	3321	(3322,3323) Digital Signal Processing	4
ECE	3351	(3352,3353) Digital Communications	4
ECE	3361	(3362,3363) Detection and Estimation Theory	4

Subject Area Elective Courses

ECE 3231 (3232,3233) Math. Methods in Electrical Engineering 2 4
ECE 3325 (3326,3327) Numerical Methods and Computer Applications 1 4
ECE 3331 (3332,3333) Analog Integrated Circuits 4
ECE 3341 (3342,3343) Electromagnetic Theory 1 4
ECE 3344 (3345,3346) Electromagnetic Theory 2 4
ECE 3371 (3372,3373) Linear Optimal Control Theory 4
ECE 3381 (3382,3383) Classical Control Theory 4
ECE 3391 (3392,3393) Computer Architecture 4
ECE 3395 (3396,3397) VLSI Design 4
ECE 3398 (3399,3400) VLSI Architectures 4
ECE 3473 Parallel Architectures for High Performance Computing 4
ECE 3497 (3498,3499) Statistical Signal Processing 4
ECE 3500 Auditory Signal Processing 4
ECE 3502 Special Topics in DSP 2
ECE 3505 (3506,3507) Digital Image Processing 4
ECE 3508 (3509,3510) Modern Spectral Analysis 4
ECE 3511 (3512,3513) Data Communications Networks 4
ECE 3514 (3515,3516) Error Correcting Codes 4
ECE 3520 Special Topics in Communication Theory 2
ECE 3526 (3527,3528) Nonlinear Systems 1 4
ECE 3529 Nonlinear Systems 2 2
ECE 3531 (3532,3533) Adaptive Signal Processing 4
ECE 3534 (3535,3536) Digital Processing of Speech Signals 4
ECE 3537 (3538,3539) Multi-User Communications Systems 4
ECE 3540 (3541,3542) Digital Control System 4
ECE 3546 (3547,3548) Advanced Topics in Stochastic Systems 4
ECE 3549 (3550,3551) Multivariable Control Systems 4
ECE 3552 System Identification and Adaptive Control 4
ECE 3553 Spread Spectrum Communications Systems 4
ECE 3554 Advanced Topics in Communications 4
ECE 3555 Statistical Pattern Recognition and Neural Networks 4
ECE 3556 Special Topics in System Theory 4
ECE 3557 Special Topics in Signal Processing 4
ECE 3558 Digital Filter Banks and Wavelets 4
ECE 3559 Wireless Communications 4
ECE 3560,3561,3562 Acoustics 1, 2, 3 ..... 2 each
ECE 3563 (3564,3565) Radar Systems 1 4
ECE 3566 Radar Systems 2 2
ECE 3567 Network Information Theory 4
ECE 3571 (3572,3573) Fourier and Binary Optics 4
ECE 3574 Fourier Optics 2 2
ECE 3579 Optoelectronics and Fiber Optics 2
ECE 3582 (3580,3581) Optics for Engineers 4
ECE 3598 Remote Sensing 4
ECE 3635 (3636,3637) Antennas and Radiation 4
ECE 3893 or 3896 Special Problems in Electrical Engineering ..... 2 or 4

Master of Science Thesis ECE 3860 8
or **Master of Science Project** ECE 3863 4

** Graduate students may take up to 8 quarter hours of electives outside the subject area elective list or outside the Electrical and Computer Engineering Department subject to approval of the Graduate Committee. Courses offered outside the Department but appear in the subject area elective list count toward the 8 quarter hours.*

Computer Engineering

Course Requirements	Full-time with Thesis	Full-time with Project	Part-time Study
Required Core Courses	8 QH	8 QH	8 QH
Subject Area Required Courses	12 QH	12 QH	12 QH
Subject Area Elective Courses	16 QH	20 QH	24 QH
Master of Science Thesis or Project	8 QH	4 QH	0 QH
Minimum Quarter Hours Required*	44 QH	44 QH	44 QH

* exclusive of any prerequisite courses

Required Core Courses (2 QH equivalents are in parentheses) **Credits**

ECE 3211 (3212,3213) Math. Methods in Electrical Engineering 1 4
ECE 3241 (3242,3243) Applied Probability and Stochastic Processes 4

Subject Area Required Courses

ECE 3311 (3312,3313) Software Engineering 1 4
ECE 3391 (3392,3393) Computer Architecture 4
ECE 3395 (3396,3397) VLSI Design 4

Subject Area Elective Courses

ECE 3221 (3222,3223) Linear Systems Analysis 4
ECE 3231 (3232,3233) Math. Methods in Electrical Engineering 2 4
ECE 3314 Software Engineering 2 2
ECE 3321 (3322,3323) Digital Signal Processing 4
ECE 3325 (3326,3327) Numerical Methods and Computer Applications 1 4
ECE 3328 Numerical Methods and Computer Applications 2 2
ECE 3331 (3332,3333) Analog Integrated Circuits 4
ECE 3341 (3342,3343) Electromagnetic Theory 1 4
ECE 3351 (3352,3353) Digital Communications 4
ECE 3361 (3362,3363) Detection and Estimation Theory 4
ECE 3371 (3372,3373) Linear Optimal Control Theory 4
ECE 3381 (3382,3383) Classical Control Theory 4
ECE 3398 (3399,3400) VLSI Architectures 4
ECE 3401 (3402,3403) Digital Systems Design w/ Hardware Description Lang. .. 4
ECE 3454 Graph Theory 2
ECE 3460 Special Topics in Computer Engineering 2
ECE 3463 (3464,3465) Robot Vision and Sensors 4
ECE 3466 (3467,3468) Robotics and Automation Systems 4
ECE 3469 (3470,3471) Fault-Tolerant Computers 4

ECE	3472	Special Topics in Robotics	4
ECE	3473	Parallel Architectures for High Performance Computing	4
ECE	3476	Special Topics in Fault-Tolerant Computing	4
ECE	3477	Testing and Design for Testability	4
ECE	3480	Distributed System	4
ECE	3483	Multiprocessor Architectures	4
ECE	3484	Combinatorial Optimization	4
ECE	3485	Digital Hardware Synthesis	4
ECE	3497	(3498,3499) Statistical Signal Processing	4
ECE	3502	Special Topics in DSP	2
ECE	3505	(3506,3507) Digital Image Processing	4
ECE	3508	(3509,3510) Modern Spectral Analysis	4
ECE	3511	(3512,3513) Data Communications Networks	4
ECE	3514	(3515,3516) Error Correcting Codes	4
ECE	3531	(3532,3533) Adaptive Signal Processing	4
ECE	3534	(3535,3536) Digital Processing of Speech Signals	4
ECE	3546	(3547,3548) Advanced Topics in Stochastic Systems	4
ECE	3549	(3550,3551) Multivariable Control Systems	4
ECE	3555	Statistical Pattern Recognition and Neural Networks	4
ECE	3558	Digital Filter Banks and Wavelets	4
ECE	3589	Optical Storage and Display	2
ECE	3626	(3627,3628) Integrated Circuits Fabrication 1	4
ECE	3629	(3630,3631) Integrated Circuits Fabrication Processes: Plasma Processing	4
ECE	3632	(3633,3637) Design & Analysis of Digital Integrated Circuits	4
ECE	3893 or 3896	Special Problems in Electrical Engineering	2 or 4
COM	3205	Fundamentals of Software Engineering	4
COM	3450	Intelligent Pattern Recognition	4
COM	3640	Parallel Algorithms	4
COM	3336	Operating Systems	4
or MIM	3107	Operating Systems and Systems Software	4

Master of Science Thesis ECE 3860 8
or **Master of Science Project** ECE 3863 4

* *Graduate students may take up to 8 quarter hours of electives outside the subject area elective list or outside the Electrical and Computer Engineering Department subject to approval of the Graduate Committee. Courses offered outside the Department but appear in the subject area elective list count toward the 8 quarter hours.*

Control Systems and Signal Processing

Course Requirements	Full-time with Thesis	Full-time with Project	Part-time Study
Required Core Courses	8 QH	8 QH	8 QH
Subject Area Required Courses	16 QH	16 QH	16 QH
Subject Area Elective Courses	12 QH	16 QH	20 QH
Master of Science Thesis or Project	8 QH	4 QH	0 QH
Minimum Quarter Hours Required*	44 QH	44 QH	44 QH

* exclusive of any prerequisite courses

Required Core Courses (2 QH equivalents are in parentheses) **Credits**

ECE 3211 (3212,3213) Math. Methods in Electrical Engineering 1 4
ECE 3241 (3242,3243) Applied Probability and Stochastic Processes 4

Subject Area Required Courses

ECE 3221 (3222,3223) Linear Systems Analysis 4
ECE 3321 (3322,3323) Digital Signal Processing 4
ECE 3371 (3372,3373) Linear Optimal Control Theory 4
ECE 3381 (3382,3383) Classical Control Theory 4

Subject Area Elective Courses

ECE 3231 (3232,3233) Math. Methods in Electrical Engineering 2 4
ECE 3325 (3326,3327) Numerical Methods and Computer Applications 1 4
ECE 3331 (3332,3333) Analog Integrated Circuits 4
ECE 3341 (3342,3343) Electromagnetic Theory 1 4
ECE 3361 (3362,3363) Detection and Estimation Theory 4
ECE 3391 (3392,3393) Digital Computer Architecture 4
ECE 3395 (3396,3397) VLSI Design 4
ECE 3398 (3399,3400) VLSI Architectures 4
ECE 3463 (3464,3465) Robot Vision and Sensors 4
ECE 3466 (3467,3468) Robotics and Automation System 4
ECE 3472 Special Topics in Robotics 4
ECE 3473 Parallel Architecture for High Performance Computing 4
ECE 3480 Distributed Systems 4
ECE 3497 (3498,3499) Statistical Signal Processing 4
ECE 3500 Auditory Signal Processing 4
ECE 3502 Special Topics in DSP 4
ECE 3505 (3506,3507) Digital Image Processing 4
ECE 3508 (3509,3510) Modern Spectral Analysis 4
ECE 3511 (3512,3513) Data Communications Networks 4
ECE 3514 (3515,3516) Error Correcting Codes 4
ECE 3520 Special Topics in Communication Theory 2
ECE 3526 (3527,3528) Nonlinear Systems 1 4
ECE 3529 Nonlinear Systems 2 2
ECE 3531 (3532,3533) Adaptive Signal Processing 4
ECE 3534 (3535,3536) Digital Processing of Speech Signals 4
ECE 3540 (3541,3542) Digital Control Systems 4
ECE 3546 (3547,3548) Advanced Topics in Stochastic Systems 4
ECE 3549 (3550,3551) Multivariable Control Systems 4
ECE 3552 System Identification and Adaptive Control 4
ECE 3555 Statistical Pattern Recognition and Neural Networks 4
ECE 3556 Special Topics in System Theory 4
ECE 3557 Special Topics in Signal Processing 4
ECE 3558 Digital Filter Banks and Wavelets 4
ECE 3560,3561,3562 Acoustics 1, 2, 3 ..... 2 each
ECE 3563 (3564,3565) Radar Systems 1 4

ECE 3566 Radar Systems 2 2
ECE 3567 Network Information Theory 4
ECE 3574 Fourier Optics 2 2
MIM 3325 Robot Mechanics and Control 4
ECE 3893 or 3896 Special Problems in Electrical Engineering ..... 2 or 4

Master of Science Thesis ECE 3860 8
or **Master of Science Project** ECE 3863 4

* *Graduate students may take up to 8 quarter hours of electives outside the subject area elective list or outside the Electrical and Computer Engineering Department subject to approval of the Graduate Committee. Courses offered outside the Department but appear in the subject area elective list count toward the 8 quarter hours.*

Electromagnetics, Plasma and Optics

Course Requirements	Full-time with Thesis	Full-time with Project	Part-time Study
Required Core Courses	8 QH	8 QH	8 QH
Subject Area Required Course	12 QH	12 QH	12 QH
Subject Area Elective Course	16 QH	20 QH	24 QH
Master of Science Thesis or Project	8 QH	4 QH	0 QH
Minimum Quarter Hours Required*	44 QH	44 QH	44 QH

* exclusive of any prerequisite courses

Required Core Courses (2 QH equivalents are in parentheses) **Credits**

ECE 3231 (3232,3233) Math. Methods in Electrical Engineering 2 4
ECE 3241 (3242,3243) Applied Probability and Stochastic Processes 4

Subject Area Required Courses

ECE 3341 (3342,3343) Electromagnetic Theory 1 4
ECE 3344 (3345,3346) Electromagnetic Theory 2 4
ECE 3347 (3348,3349) Computational Methods in Electromagnetics 4

Subject Area Electives Courses

ECE 3211 (3212,3213) Math. Methods in Electrical Engineering 1 4
ECE 3221 (3222,3223) Linear Systems Analysis 4
ECE 3321 (3322,3323) Digital Signal Processing 4
ECE 3384 (3385,3386) Solid State Devices 1 4
ECE 3395 (3396,3397) VLSI Design 4
ECE 3557 Special Topics in Signal Processing 4
ECE 3558 Digital Filter Banks and Wavelets 4
ECE 3560,3561,3562 Acoustics 1, 2, 3 ..... 2 each
ECE 3563 (3564,3565) Radar Systems 1 4
ECE 3566 Radar Systems 2 2
ECE 3571 (3572,3573) Fourier and Binary Optics 4
ECE 3574 Fourier Optics 2 2
ECE 3575 Lasers 4

ECE	3576,3577,3578	Lasers 1, 2, 3	2 each
ECE	3579	Optoelectronics and Fiber Optics	2
ECE	3582	(3580,3581) Optics for Engineers	4
ECE	3583,3584,3585	Optical Properties of Matter 1, 2, 3	2 each
ECE	3586	(3587,3588) Optical Detection	4
ECE	3589	Optical Storage and Display	2
ECE	3590	Optical Instrumentation Design	2
ECE	3591	Modern Spectroscopy	2
ECE	3593	Plasma Engineering	4
ECE	3594	(3595,3596) Plasma Theory	4
ECE	3597	Optical Properties of Matter	4
ECE	3598	Remote Sensing	4
ECE	3599	IR Imaging	2
ECE	3600	(3601,3602) Microwave Properties of Materials	4
ECE	3603	(3604,3605) Propagation in Artificial Structures	4
ECE	3606	(3607,3608) Applications of Plasma Engineering	4
ECE	3609	Special Topics in Electromagnetics	4
ECE	3613	(3614,3615) Solid State Microwave Circuits	4
ECE	3626	(3627,3628) Integrated Circuits Fabrication 1	4
ECE	3629	(3630,3631) Integrated Circuits Fabrication Processes : Plasma Processing	4
ECE	3635	(3636,3637) Antennas and Radiation	4
ECE	3638	(3639,3640) Microwave Electron Devices	4
ECE	3641	High Speed/High Frequency Solid State Devices	4
ECE	3644	Passive Microwave Circuits	4
ECE	3893 or 3896	Special Problems in Electrical Engineering	2 or 4

Master of Science Thesis ECE 3860 8
or **Master of Science Project** ECE 3863 4

* *Graduate students may take up to 8 quarter hours of electives outside the subject area elective list or outside the Electrical and Computer Engineering Department subject to approval of the Graduate Committee. Courses offered outside the Department but appear in the subject area elective list count toward the 8 quarter hours.*

Electronic Circuits and Semiconductor Devices

Course Requirements	**Full-time with Thesis**	**Full-time with Project**	**Part-time Study**
Required Core Courses	8 QH	8 QH	8 QH
Subject Area Required Courses	16 QH	16 QH	16 QH
Subject Area Elective Courses	12 QH	16 QH	20 QH
Master of Science Thesis or Project	8 QH	4 QH	0 QH
Minimum Quarter Hours Required*	44 QH	44 QH	44 QH

* exclusive of any prerequisite courses

Required Core Courses (2 QH equivalents are in parentheses) **Credits**

ECE	3211	(3212,3213) Math. Methods in Electrical Engineering 1	4
ECE	3241	(3242,3243) Applied Probability and Stochastic Processes	4

Subject Area Required Courses

ECE	3221	(3222,3223)	Linear Systems Analysis 4
ECE	3331	(3332,3333)	Analog Integrated Circuits 4
ECE	3384	(3385,3386)	Solid State Devices 1 4
ECE	3395	(3396,3397)	VLSI Design 4

Subject Area Elective Courses

ECE	3321	(3322,3323)	Digital Signal Processing 4
ECE	3341	(3342,3343)	Electromagnetic Theory 1 4
ECE	3344	(3345,3346)	Electromagnetic Theory 2 4
ECE	3388	(3389,3390)	Solid State Devices 2 4
ECE	3391	(3392,3393)	Computer Architecture 4
ECE	3398	(3399,3400)	VLSI Architectures 4
ECE	3401	(3402,3403)	Digital System Design w/ Hardware Description Lang 4
ECE	3610	(3611,3612)	Electronics of Analog Signal Processing 4
ECE	3613	(3614,3615)	Solid State Microwave Circuits 4
ECE	3616	(3617,3618)	Active Network Synthesis and Design 4
ECE	3626	(3627,3628)	Integrated Circuits Fabrication 1 4
ECE	3629	(3630,3631)	Integrated Circuits Fabrication Processes : Plasma Processing 4
ECE	3632	(3633,3634)	Design and Analysis of Digital Integrated Circuits. 4
ECE	3638	(3639,3640)	Microwave Electron Devices 4
ECE	3641		High Speed/High Frequency Solid State Devices 4
ECE	3642		Microelectromechanical Systems 4
ECE	3644		Passive Microwave Circuits 4
ECE	3893 or 3896		Special Problems in Electrical Engineering ..... 2 or 4

Master of Science Thesis ECE 3860 8
or **Master of Science Project** ECE 3863 4

* *Graduate students may take up to 8 quarter hours of electives outside the subject area elective list or outside the Electrical and Computer Engineering Department subject to approval of the Graduate Committee. Courses offered outside the Department but appear in the subject area elective list count toward the 8 quarter hours.*

Power Systems

Course Requirements	**Full-time with Thesis**	**Full-time with Project**	**Part-time Study**
Required Core Courses	12 QH	12 QH	12 QH
Subject Area Required Courses	12 QH	12 QH	12 QH
Subject Area Elective Courses	12 QH	16 QH	20 QH
Master of Science Thesis or Project	8 QH	4 QH	0 QH
Minimum Quarter Hours Required*	44 QH	44 QH	44 QH

* exclusive of any prerequisite courses

Required Core Courses (2 QH equivalents are in parentheses) **Credits**

ECE	3211	(3212,3213)	Math. Methods in Electrical Engineering 1 4
ECE	3221	(3222,3223)	Linear Systems Analysis 4

ECE 3241 (3242,3243) Applied Probability and Stochastic Processes 4

Subject Area Required Courses

ECE 3310 (3308,3309) Electrical Machinery Theory 4
ECE 3432 Power Systems Operation and Control 4
ECE 3433 Power Electronics 4

Subject Area Elective Courses

ECE 3301 (3302,3303) Power Circuit Analysis 4
ECE 3304 Motor Control with DC Drives 2
ECE 3305,3306 Computational Methods in Power Systems 1, 2 ..... 2 each
ECE 3307 Motor Control with AC Drives 2
ECE 3321 (3322,3323) Digital Signal Processing 4
ECE 3341 (3342,3343) Electromagnetic Field Theory 1 4
ECE 3344 (3345,3346) Electromagnetic Field Theory 2 4
ECE 3371 (3372,3373) Linear Optimal Control Theory 4
ECE 3381 (3382,3383) Classical Control Theory 4
ECE 3412 Power Systems Planning 4
ECE 3415 Power Systems Protection 2
ECE 3416 Electromagnetic Power Systems Transients 2
ECE 3417 Analysis of Equipment Failure 2
ECE 3423 Special Topics in Power 2
ECE 3424 Electromechanical Power System Dynamics 2
ECE 3429 (3430,3431) Electric Power Transmission ..... 2 each
MIM 3215 Engineering Economy 4
MIM 3217 Engineering Project Management 4
MIM 3700 General Thermodynamics 4

Master of Science Thesis ECE 3860 8
or **Master of Science Project** ECE 3863 4

* *Graduate students may take up to 8 quarter hours of electives outside the subject area elective list or outside the Electrical and Computer Engineering Department subject to approval of the Graduate Committee. Courses offered outside the Department but appear in the subject area elective list count toward the 8 quarter hours.*

THE DOCTOR OF PHILOSOPHY DEGREE

Qualifying Examination and Degree Candidacy

First, and foremost, the Ph.D. Qualifying Examination is the entrance examination for the admission to the doctoral program. In addition, this examination has the dual purpose of 1: serving as an indicator of the student's capability for successful completion of the program, and 2: serving as a guide to his or her advisor in developing a suitable plan of study tailored to the individual needs of the candidate. A student who has received approval to take the qualifying examination is considered a pre-doctoral student until such time as he or she passes the examination. Upon successful completion of the qualifying examination he or she becomes a Ph.D. candidate.

With these goals in mind, the candidate is urged to take the qualifying examination early in his or her graduate program (i.e., not later than the successful completion of 40 quarter hours of graduate

work). The examination is composed of a written and an oral part and is usually given in the spring quarter of each academic year. For the written part, the student is required to choose *three* out of the following five areas of concentration:

1. Circuits and Electronics
2. Computer Engineering
3. Energy Conversion and Power Systems
4. Fields, Waves and Optics
5. Signals and Systems

One of the three areas should be that closest to the specialty area in which the student plans to do his or her doctoral thesis work.

The oral part is designed to test general comprehension. Together, the oral and written portions of the examination are designed to test the factual knowledge of a typical undergraduate Electrical Engineering program. If the examination is failed it may be repeated only with permission of the Graduate Committee upon recommendation of the Ph.D. Qualifying Examination Committee.

Course Requirements

Successful completion of a doctoral program normally requires a minimum of 70 quarter hours of satisfactory graduate level work beyond the Bachelor of Science degree, exclusive of doctoral seminar (required), doctoral reading, and doctoral dissertation.

The course work must include a three-course sequence (12 QH graduate level courses) in each of two minor areas. One minor must be in the Department of Electrical and Computer Engineering. The second minor must be in science, applied science, or engineering. Both minors must be outside of the candidate's proposed major area.

Upon successful completion of the Ph.D. qualifying examination and the majority of required course work, the student is required to register in three consecutive quarters for ECE 3880 (Doctoral Thesis). Upon completion of this sequence, the student is required to register for ECE 3799 (Ph.D. Thesis Continuation) in every quarter until the dissertation has been completed. Students may not register for continuation until the three-quarter thesis sequence has been fulfilled.

Technical Writing Requirement

Successful completion of a graduate-level technical writing course is required for all Ph.D. candidates.

Residence Requirement

The residence requirement is satisfied by one year of full-time graduate work or two consecutive years of part-time graduate work. In the latter case, a detailed time schedule must be approved by the student's advisor in order to give evidence that at least half of the time is being devoted to the requirements of the graduate school.

Dissertation

The candidate's dissertation research is directed by a Dissertation Advisor, whom he or she shall select after establishing candidacy. A Dissertation Committee shall be formed consisting of the Advisor and two full-time faculty members with background relevant to the thesis topic. The Committee may also include a person from industry. The Dissertation Committee will approve the dissertation in final form.

Comprehensive Examination

Within three years of establishment of degree candidacy, the student will be required to demonstrate by means of a comprehensive examination a subject matter knowledge satisfactory for the award of the degree.

The comprehensive examination is an oral examination open to the Department of Electrical and Computer Engineering faculty (assistant professor and above in rank) and administered by the student's Dissertation Committee. Departmental faculty will be informed of the examination via a departmental notice at least one week prior to the examination. Normally the examination will be given at the time the Dissertation Proposal is submitted to the Dissertation Committee for approval. As part of this examination the Dissertation Committee will review the student's doctoral program and his or her performance in graduate courses, as well as examine the student on subject matter related to graduate studies and dissertation area.

Final Oral Examination

The final oral examination will include the subject matter of the doctoral dissertation and significant developments in the field of the dissertation work. Other related fields may be included if recommended by the examining committee.

FACULTY

Fabrizio Lombardi, Ph.D., Chairperson and ITC Professor

Professors

Buus, Soren, Ph.D., Northeastern University; psychoacoustics, signal processing, microprocessors

Chan, Chung, Ph.D., University of Iowa; plasmas, electromagnetics

Devaney, Anthony, Ph.D., University of Rochester; tomography, electromagnetic wave propagation, inverse scattering

Grabel, Arvin, Sc.D., New York University; circuit theory, electronics

Hanania, Jack, Ph.D., Leeds (England); power systems, electromagnetics

Lombardi, Fabrizio, Ph.D., University College, London England; digital systems fault tolerant computing, CAD, manufacturing of Ics, configurable computing

Mulukulta, Sarma, Ph.D., University of Colorado; power systems, electrical machinery, electromagnetic theory and its applications to electrical machines

Prasad, Sheila, Ph.D., Harvard University; microwave solid state devices and circuits

Proakis, John, Ph.D., Harvard University; digital communications, adaptive filtering, estimation, and digital signal processing

Sandler, Sheldon, Ph.D., Harvard University; electromagnetics, antennas, pattern recognition, robotics

Schetzen, Martin, Sc.D., Massachusetts Institute of Technology; systems theory, control systems, theory of nonlinear systems

Serafim, Philip, Sc.D., Massachusetts Institute of Technology; electromagnetics, remote sensing

Silevitch, Michael, Ph.D., Northeastern University; plasma theory, applications of plasma theory to auroral phenomena

Vittoria, Carmine, Ph.D., Yale University; electromagnetics, magnetic materials, microwave circuits

Associate Professors

Brady, David, Ph.D., Princeton University; digital communications, multi-user communications
Brooks, Dana, Ph.D., Northeastern University; digital signal processing
Crisman, Jill, Ph.D., Carnegie-Mellon University; robotics, robot vision
Hopwood, Jeffrey, Ph.D., Michigan State; plasma processing, IC fabrication
Ingle, Vinay, Ph.D., Rensselaer Polytechnic Institute; signal processing, image processing
Kokar, Mieczyslaw, Ph.D., Technical University of Wroclaw; artificial intelligence, operating systems
Leeser, Miriam, Ph.D., Cambridge University; CAD, VLSI design, rapid system prototyping
Lev-Ari, Hanoch, Ph.D., Stanford University; digital signal processing, adaptive filtering
Manolakos, Elias, Ph.D., University of Southern California; computer engineering, VLSI design, signal processing algorithms
McGruer, Nicol, Ph.D., Michigan State University; solid state devices, IC fabrication
McKnight, Stephen, Ph.D., University of Maryland; semiconductor devices and materials, electro-optics, electromagnetics
McLaughlin, David, Ph.D., University of Massachusetts; radar systems, electromagnetics
Raghavan, Ram, Ph.D., University of Massachusetts; statistical signal processing and array processing
Rappaport, Carey, Sc.D., Massachusetts Institute of Technology; electromagnetics, microwaves
Salehi, Masoud, Ph.D., Stanford University; information theory, coding
Shafai, Bahram, Ph.D., George Washington University; control systems, digital signal processing
Stankovic, Aleksander, Ph.D., Massachusetts Institute of Technology; power systems, power electronics, control systems
Stavrakakis, Ioannis, Ph.D., University of Virginia; communication networks
Tadmor, Gilead, Ph.D., Weizmann Institute, Israel; control systems
Vai, Man-Kuan, Ph.D., Michigan University; VLSI design, computer engineering
Zavracky, Paul, Ph.D., Tufts University; microsensor devices and device fabrication

Assistant Professors

McIlrath, Lisa, Sc.D., Massachusetts Institute of Technology; analog electronics, VLSI
Kaeli, David, Ph.D., Rutgers University; computer architecture, software engineering
Lehman, Bradley, Ph.D., Georgia Institute of Technology; control systems, power systems
Meleis, Waleed, Ph.D., University of Michigan; computer engineering, computer architecture; performance optimization
Miller, Eric, Sc.D., Massachusetts Institute of Technology; signal and image processing

PROGRAM ADVISORS

An advisor will be assigned to you upon admission to the Graduate School. If you are unable to reach your advisor, you may call the ECE Department office at (617) 373-5281.

COURSE DESCRIPTIONS

Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering sheets to determine what courses are actually offered in any given quarter and at what day and time.

ECE 3100 Introduction to Circuits and Systems (4QH)
Fall Quarter

The circuit elements (R, L and C) are introduced. Kirchoff's Laws, Tellegan and Thevenin's Theorem. Mesh and nodal analysis. Development of system function approach, Laplace and Fourier transform theory applied to circuit analysis. Sinusoidal steady-state, n-port network theory and power and energy concepts. *Prep. Admission to Graduate School.*

ECE 3101 Introduction to Electronics (4QH)
Winter Quarter

Characteristics of the theoretical physical junction. The Ebers-Moll model for bipolar junction transistors, characteristics of bipolar and field-effect devices, basic digital inverters and logic gates and various logic families. Use of transistors in the design of analog circuits. Biasing, linearized incremental models, load lines, signal flowgraphs, frequency response and gain calculation for single and cascaded stages. *Prep. ECE 3100 or equivalent.*

ECE 3102 Introduction to Electromagnetic Field Theory (4QH)
Spring Quarter

Definition of scalar and vector fields; vector calculus; concepts of gradient, divergence, curl and the "del" operator; free-space electrostatics; the generalization of the Maxwell equations to the case of time-varying fields; Faraday induction law, wave equations and the place wave solution. *Prep. ECE 3100 or equivalent.*

ECE 3103 Introduction to Digital Systems Design (4QH)
Fall Quarter

Basic components of digital systems and methods for their analysis and design, combinational and sequential circuits, integrated circuit logic families and functional building blocks, registers, counters, decoders, multiplexers and memories. Data representation and coding techniques. Central processor alternatives; instruction formats, addressing modes, bus structures, arithmetic units, timing analysis and stacks. Algorithms for arithmetic operations with various data representations. *Prep. Admission to Graduate School.*

ECE 3104 Introduction to Communications (4QH)
Spring Quarter

Review of system theory, convolution, Fourier series, Fourier integral, signal analysis, Fourier methods, correlation functions, density functions, power spectra, amplitude modulation, frequency modulation, phase modulation, sampling theory and digital modulation techniques. *Prep. ECE 3108 or equivalent.*

ECE 3108 Introduction to Signals and Systems (4QH)
Winter Quarter

Description and analysis of continuous and discrete time signals and systems. Time domain analysis of linear, time-invariant (LTI) systems. Frequency domain analysis of signals and LTI systems. Laplace and z-transforms. State space descriptions of continuous and discrete time systems. *Prep. ECE 3100 or equivalent.*

ECE 3109 Introduction to Computer Systems (4QH)
Fall Quarter

The course will comprise two central topics: 1) data structures and algorithms, and 2) computer architecture and organization. The purpose of this course is to provide a non-electrical engineering student with sufficient background to be able to enter graduate-level Computer Engineering courses. Data structures, including stacks, lists, heaps, and other abstract data types will be covered. Algorithm complexity will be covered for searches, sorts, parses, and popular algorithms. Programming projects will involve implementing many of these data structures and algorithms. All programming will be done in C or C++. The computer architecture and organization portion of this course will cover assembly language, instruction sets, memory, I/O, and the basic logic building blocks used to construct such systems. System software will also be discussed, including compilers, operating systems, and I/O management. *Prep. Working knowledge of C programming language.*

ECE 3120 Power Circuit Analysis 1 (2QH)
Fall Quarter
Fundamental concepts of single-phase and poly-phase power systems; definitions of terms; use of per unit quantities; equivalent circuits of symmetrical 3-phase systems; introduction of symmetrical components; short circuits on systems with a single power source. *Prep. BSEE or ECE 3100 & ECE 3102.*

ECE 3130 Electrical Machinery Theory 1 (2QH)
Fall Quarter
Review of magnetic circuit concepts and electromechanical energy-conversion principles; steady-state analysis of transformers, synchronous machines, and induction machines. *Prep. BSEE or ECE 3100 and ECE 3102.*

ECE 3211 Mathematical Methods in Electrical Engineering I (4QH)
Fall and Winter Quarters
Fundamental Algebraic Concepts; Sets, functions, relations, operations; Algebraic Structures; group, rings, fields, homomorphisms, polynomials; Vector Spaces and Linear Operators; representations, matrices and linear algebraic equations, orthogonality, equivalence and similarity transformations, eigenvalues and eigenvectors, canonical forms, functions of a square matrix, quadratic forms and congruence transformations, orthogonal transformations; Introduction to Polynomial Matrices; Applications to Communications and Control Theory. *Prep. Admission to Graduate School.*

ECE 3212 Mathematical Methods in Electrical Engineering 1-A (2QH)
Fall and Winter Quarters
ECE 3212 and ECE 3213 cover the same material with the same prerequisites as ECE 3211, but in two 2QH courses.

ECE 3213 Mathematical Methods in Electrical Engineering 1-B (2QH)
Winter and Spring Quarters
Continuation of ECE 3212. *Prep. ECE 3212.*

ECE 3221 Linear Systems Analysis (4QH)
Winter and Spring Quarters
Introduction to the state variable theory of continuous and discrete linear systems. Standard canonical representations, the concept of state and the representation of interconnected systems, linear spaces, the state equations and their solution, stability, introduction to the general control problem in terms of controllability and observability. *Prep. ECE 3211, ECE 3108 or equivalent.*

ECE 3222 Linear Systems Analysis A (2QH)
Fall and Winter Quarters
ECE 3222 and ECE 3223 cover the same material with the same prerequisites as ECE 3221, but in two 2QH courses.

ECE 3223 Linear Systems Analysis B (2QH)
Winter and Spring Quarters
Continuation of ECE 3222. *Prep. ECE 3222.*

ECE 3231 Mathematical Methods in Electrical Engineering 2 (4QH)
Fall Quarter
Complex variable theory; analytic functions and Cauchy-Riemann equations, complex integration and Cauchy integral formula, Taylor and Laurent Series, the residue theorem, conformal mapping; Laplace transform and its applications, problems in partial differential equations; generalized Fourier Series and Green's functions; general integral transforms; Sturm-Liouville, Fourier, Hankel, Legendre and other integral transforms. *Prep. Admission to Graduate School.*

ECE 3232 Mathematical Methods in Electrical Engineering 2-A (2QH)
Fall Quarter
ECE 3232 and ECE 3233 cover the same material with the same prerequisites as ECE 3231, but in two 2QH courses.

ECE 3233 Mathematical Methods in Electrical Engineering 2-B (2QH)
Winter Quarter
Continuation of ECE 3222. *Prep. ECE 3222.*

ECE 3241 Applied Probability and Stochastic Processes (4QH)
Fall and Winter Quarters
Introductory probability, sample space and random variables, examples of discrete and continuous probability distribution functions, averages, moments and characteristic function, multivariate distributions, change of variables and functions of variables, central limit theorem, description of stochastic vectors. General concepts of stochastic processes, stationarity and ergodicity, stochastic continuity and differentiation, the Gaussian process, linear systems with stochastic inputs, correlation functions and power spectra, matched filtering, stochastic orthogonality and linear mean-square estimation filtering and prediction. *Prep. ECE 3108 or equivalent.*

ECE 3242 Applied Probability and Stochastic Processes A (2QH)
Fall and Winter Quarters
ECE 3242 and ECE 3243 cover the same material

with the same prerequisites as ECE 3241, but in two 2QH courses.

ECE 3243 Applied Probability and Stochastic Processes B (2QH)
Winter and Spring Quarters
Continuation of ECE 3242. *Prep. ECE 3242.*

ECE 3301 Power Circuit Analysis (4QH)
Spring Quarter
A continuation of ECE 3120 Power Circuit Analysis 1. Symmetrical components are applied to the solution of power systems under unbalanced fault conditions - phase to ground, two phase to ground, phase to phase, open conductor. Formulation of the Impedance Matrix and its use in the solution of short circuits by computer methods is covered. Economic Dispatch methods, the solution of the Power Flow Problem using Newton-Raphson with the Stott-Alsac approximation, and solution of the Transient Stability Problem with the Equal-Area Method for single machines and computer solution of multi-machine power systems is included. *Prep. ECE 3120.*

ECE 3302 Power Circuit Analysis A (2QH)
Winter Quarter
ECE 3302 and ECE 3303 cover the same material with the same prerequisite as ECE 3301, but in two 2QH courses.

ECE 3303 Power Circuit Analysis B (2QH)
Spring Quarter
Continuation of ECE 3302. *Prep. ECE 3302.*

ECE 3304 Motor Control with DC Drives (2QH)
Fall Quarter
DC motor dynamics and transfer function. Single phase and three phase rectifier circuits with motor loads. Feedback control, chopper controlled DC motors, examples from industry and design considerations. *Prep. BSEE or ECE 3100 and ECE 3101, or equivalent.*

ECE 3305 Computational Methods in Power Systems 1 (2QH)
Fall Quarter
Techniques used in solving power system problems with the digital computer. Matrix formulations are examined, followed by a detailed treatment of the short-circuit problem, including balanced and unbalanced faults. Various iterative techniques are studied for the solution of the power-flow problem. *Prep. ECE 3120.*

ECE 3306 Computational Methods in Power Systems 2 (2QH)
Winter Quarter
Practical considerations of solving large scale networks. Network reductions, distribution factors and contingency analysis techniques. Digital models for regulated generators, fixed and load tap changing transformers and HVDC transmission lines. Computer methods for economic dispatch, loss coefficient application of pumped hydro are developed. *Prep. ECE 3305.*

ECE 3307 Motor Control with AC Drives (2QH)
Winter Quarter
Induction and synchronous motor equivalent circuits and characteristics - operation of inverters - pulse-width modulation, voltage-source inverters, current-source inverters, load-commutated inverters and cycloconverters - feedback control - applications and design considerations. *Prep. ECE 3310.*

ECE 3308 Electrical Machinery Theory 2 (2QH)
Winter Quarter
Mathematical description of a synchronous machine; per-unit representation; steady-state theory and transient performance; flux distribution and saturation in synchronous machines. *Prep. ECE 3130.*

ECE 3309 Electrical Machinery Theory 3 (2QH)
Spring Quarter
Review of transient behavior of synchronous machines; stability studies and excitation systems; synchronous machine modeling; generator protection; trends in development of large generators. *Prep. ECE 3308.*

ECE 3310 Electrical Machinery Theory (4QH)
As Announced
ECE 3310 covers the same course material and has the same prerequisites as ECE 3308 and ECE 3309 combined.

ECE 3311 Software Engineering I (4QH)
Fall Quarter
This course presents two main topics. First traditional methods in Software Engineering are presented. This includes the various development models, requirements, specification, design, prototyping, implementation, test, and maintenance. The second topic discusses object-oriented design principles. Concepts such as encapsulation, inheritance, and polymorphism are discussed. A software project will be assigned that will contrast the differences between function-

oriented and object-oriented design. *Prep. Working knowledge of the C programming language.*

ECE 3312 Software Engineering 1-A (2QH)
Fall and Winter Quarters
ECE 3312 and ECE 3313 cover the same material with the same prerequisites as ECE 3311, but in two 2QH courses.

ECE 3313 Software Engineering 1-B (2QH)
Winter and Spring Quarters
Continuation of ECE 3312. *Prep. ECE 3312.*

ECE 3314 Software Engineering 2 (2QH)
Spring Quarter
Focus turns away from the general issues of the first two courses in this sequence and toward a very specific issue, modular design of software. Issues of stepwise-refinement and top-down design are explored in depth and organizational/data-flow issues are considered. *Prep. ECE 3311 or ECE 3313.*

ECE 3321 Digital Signal Processing (4QH)
Winter and Spring Quarters
Theory and practice of modern signal processing techniques. Characteristics of discrete signals and systems, sampling and A/D conversion; the z-transform, the Fourier transform and the discrete Fourier transform; fast Fourier transform algorithms; design techniques for IIR and FIR digital filters; multirate digital filters; quantization effects in digital signal processing. *Prep. ECE 3221.*

ECE 3322 Digital Signal Processing A (2QH)
Fall and Winter Quarters
ECE 3322 and ECE 3323 cover the same material with the same prerequisites as ECE 3321, but in two 2QH courses.

ECE 3323 Digital Signal Processing B (2QH)
Winter and Spring Quarters
Continuation of ECE 3322. *Prep. ECE 3322.*

ECE 3325 Numerical Methods and Computer Applications I (4QH)
Winter Quarter
Survey of numerical methods applied to engineering and scientific problems with emphasis on machine implementation and problem solving; roundoff and cumulative errors; roots of polynomials and nonlinear functions; systems of linear and nonlinear algebraic equations; orthogonal function, least square Chebyshev approximation of functions; interpolation; numeric quadrature; ordinary and partial differential equations. *Prep. Admission to Graduate School and a working knowledge of FORTRAN.*

ECE 3326 Numerical Methods and Computer Applications 1-A (2QH)
Fall and Winter Quarters
ECE 3326 and ECE 3327 cover the same material with the same prerequisites as ECE 3325, but in two 2QH courses.

ECE 3327 Numerical Methods and Computer Applications 1-B (2QH)
Winter and Spring Quarters
Continuation of ECE 3326. *Prep. ECE 3326.*

ECE 3328 Numerical Methods and Computer Applications 2 (2QH)
Spring Quarter
Spectral analysis, including fast Fourier transforms, Hilbert transforms, convolution, and correlation techniques. Optimization, including dynamic programming and steepest descent techniques. PERT and linear programming. Other selected topics. *Prep. ECE 3325 or ECE 3327.*

ECE 3331 Analog Integrated Circuits (4QH)
Fall Quarter
Active transistor circuits and systems are treated with emphasis on modern integrated circuit architectures. Bipolar and field-effect (NMOS and CMOS) implementations of analog circuits are presented. Characteristics and behaviors of analog I.C. structures are explored through the study of circuits such as, operational amplifiers, instrumentation amplifiers, voltage comparators, various types of filter configuration and integrators as well as multipliers and logarithmic amplifiers. Features covered include linearity, dynamic range, slew-rate limiting and speed and gain bandwidth trade-offs. The role of feedback in stabilizing, linearizing and otherwise enhancing the performance of analog circuits is treated in detail. Noise limitations on circuit performance are explored. Noise models of devices and circuits are developed, leading to the prediction of system noise performance and techniques for optimizing signal-to-noise ratios. *Prep. ECE 3101 or equivalent.*

ECE 3332 Analog Integrated Circuits A (2QH)
Fall Quarter
ECE 3332 and ECE 3333 cover the same material with the same prerequisites as ECE 3331, but in two 2QH courses.

ECE 3333 Analog Integrated Circuits B (2QH)
Winter Quarter
Continuation of ECE 3332. *Prep. ECE 3332*

ECE 3341 Electromagnetic Theory 1 (4QH)
Fall Quarter
Emphasis is on the fundamental equations, their

physical meaning, principal mathematical techniques and important engineering applications. Sources of the EM field; Lorentz force equation; integral form of Maxwell's equations and point relations (differential equations and boundary conditions); electromagnetic energy and power; propagation of plane waves in homogeneous media; reflection and transmission; scalar and vector potentials; solutions in the absence of boundaries for static and dynamic problems, with or without symmetry; solutions to boundary value problems; Green's functions; transmission lines, rectangular waveguides, and resonators; dielectric slab guide. *Prep. ECE 3102 or equivalent.*

ECE 3342 Electromagnetic Theory 1-A (2QH)
Fall Quarter
ECE 3342 and ECE 3343 cover the same material with the same prerequisites as ECE 3341, but in two 2QH courses.

ECE 3343 Electromagnetic Theory 1-B (2QH)
Winter Quarter
Continuation of ECE 3342. *Prep. ECE 3342.*

ECE 3344 Electromagnetic Theory 2 (4QH)
Winter Quarter
Examination of important electrodynamic applications by the use of advanced mathematical techniques. General theory of waveguides and resonators with application to the cylindrical geometry; Dielectric rod waveguide; optical fibers; radiation; linear antennas; loop antenna; linear arrays; ray optics; scattering and diffraction of waves for planar, cylindrical and spherical geometries; effects of random media. *Prep. ECE 3341.*

ECE 3345 Electromagnetic Theory 2-A (2QH)
Winter Quarter
ECE 3345 and ECE 3346 cover the same material with the same prerequisites as ECE 3344, but in two 2QH courses.

ECE 3346 Electromagnetic Theory 2-B (2QH)
Spring Quarter
Continuation of ECE 3345. *Prep. ECE 3345.*

ECE 3347 Computational Methods in Electromagnetics (4QH)
Winter Quarter
Solutions to problems in electromagnetics are presented using a wide variety of numerical and computational methods. Finite difference approximations of partial differential equations and the Finite Difference Time Domain method of simulating electromagnetic wave propagation and scattering will be discussed in detail. Moment methods will be used to solve the integral equations related to currents and charges on wire structures. Finite element and higher-order finite difference methods will be used to solve problems in electrostatics and wave propagation. Efficient matrix methods, relaxation methods, the conjugate gradient technique, and multidimensional Newton's method will be presented in the context of electromagnetic field simulation. *Prep. ECE 3341.*

ECE 3348 Computational Methods in Electromagnetics A (2QH)
Fall Quarter
ECE 3348 and ECE 3349 cover the same material with the same prerequisites as ECE 3347, but in two 2QH courses.

ECE 3349 Computational Methods in Electromagnetics B (2QH)
Winter Quarter
Continuation of ECE 3348. *Prep. ECE 3348.*

ECE 3351 Digital Communications (4QH)
Winter Quarter
The theoretical and practical aspects of digital communications in the presence of channel distortion and additive noise. Topics covered include the basic binary and M-ary modulation techniques, namely, PSK, PAM, FSK, orthogonal and biorthogonal signals, and their performance in an additive Gaussian noise channel; signal waveforms constructed from binary block and convolutional codes; hard-decision decoding and soft-decision decoding of coded signal waveforms; performance of coded waveforms in an additive white Gaussian noise channel; trellis-coded modulation. *Prep. ECE 3241 and ECE 3104 or equivalent.*

ECE 3352 Digital Communications A (2QH)
Fall Quarter
ECE 3352 and ECE 3353 cover the same material with the same prerequisites as ECE 3351, but in two 2QH courses.

ECE 3353 Digital Communications B (2QH)
Winter Quarter
Continuation of ECE 3352. *Prep. ECE 3352.*

ECE 3361 Detection and Estimation Theory (4QH)
Winter Quarter
The classical theory of detection and estimation of signals in noise with emphasis on implementation of the theory. Particular topics include: hypothesis testing criteria; coherent detection of M-ary signals; diversity receiver; calculation of error probabilities. Detection in colored noise; parameter estimation using Bayes, maximum-likelihood, a maximum land posteriori criteria; applications of the theory to digital communications and radar. *Prep. ECE 3241.*

ECE 3362 Detection and Estimation Theory A (2QH)
Winter Quarter
ECE 3362 and ECE 3363 cover the same material with the same prerequisites as ECE 3361, but in two 2QH courses.

ECE 3363 Detection and Estimation Theory B (2QH)
Spring Quarter
Continuation of ECE 3362. *Prep. ECE 3362.*

ECE 3371 Linear Optimal Control Theory (4QH)
Winter Quarter
State-space, time-domain techniques for analyzing and designing linear optimal control systems will be explored. The goal is to introduce basic concepts of dynamic optimization and then to apply them to problems of short and long terms optimal control, stabilization, state estimation and filtering, stochastic and worst-case robust control. Emphasis will be placed on linear quadratic optimization. *Prep. ECE 3221 and ECE 3241.*

ECE 3372 Linear Optimal Control Theory A (2QH)
Winter Quarter
ECE 3372 and ECE 3373 cover the same material with the same prerequisites as ECE 3371, but in two 2QH courses.

ECE 3373 Linear Optimal Control Theory B (2QH)
Spring Quarter
Continuation of ECE 3372. *Prep. ECE 3372.*

ECE 3381 Classical Control Theory (4QH)
Fall Quarter
Basic systems modeling; steady state and transient response analysis. Introduction to root-locus plots, Bode plots, Nyquist plots, and Nichols chart. The design of first order cascade and feedback compensators using the above plots. Pole-zero synthesis techniques and design techniques for the optimal linear regulator problem. *Prep. ECE 3108 or equivalent.*

ECE 3382 Classical Control Theory A (2QH)
Fall Quarter
ECE 3382 and ECE 3383 cover the same material with the same prerequisites as ECE 3381, but in two 2QH courses.

ECE 3383 Classical Control Theory B (2QH)
Winter Quarter
Continuation of ECE 3382. *Prep. ECE 3382.*

ECE 3384 Solid State Devices 1 (4QH)
Fall Quarter
Crystal structure, quantum theory, energy bands, semiconductor statistics, generation and recombination, carrier transport phenomena, p-n junction theory, charge storage and diode transients. *Prep. ECE 3101 or equivalent.*

ECE 3385 Solid State Devices 1-A (2QH)
Fall Quarter
ECE 3385 and ECE 3386 cover the same material with the same prerequisites as ECE 3384, but in two 2QH courses. *Prep. ECE 3101 or equivalent.*

ECE 3386 Solid State Devices 1-B (2QH)
Winter Quarter
Continuation of ECE 3385. *Prep. ECE 3385.*

ECE 3388 Solid State Devices 2 (4QH)
Winter Quarter
Bipolar junction transistors, Gummel-Poon model, metal-semiconductor contacts, methods of measurement of barrier height, MIS diode, C-V measurement to evaluate the interface-trapped charges: MOSFET device and structure, charge control model, device scaling, short channel effects, submicron structures; CMOS. *Prep. ECE 3384.*

ECE 3389 Solid State Devices 2-A (2QH)
Winter Quarter
ECE 3389 and 3390 cover the same material with the same prerequisites as ECE 3388, but in two 2QH courses. *Prep. ECE 3384.*

ECE 3390 Solid State Devices 2-B (2QH)
Spring Quarter
Continuation of ECE 3389. *Prep. ECE 3389.*

ECE 3391 Computer Architecture (4QH)
Winter Quarter
This course presents many of the issues involved in the design and analysis of new and evolving computer architectures. Topics include all aspects of the system including the microprocessor, memory, I/O and networking. The course emphasizes the connection between architecture and the underlying software which drives the architecture. Focus areas include: pipelining, superscalar, out of order execution and completion, dataflow, caching, prefetching, virtual memory, RAID and ATM switching. Performance analysis is another fundamental theme of this course. A project is assigned that involves the creation of a trace-driven simulation model to study the performance of various hardware or software architectural features. The course will also provide a survey of the current state-of-art in processor architectures and will provide additional readings from recent research in

the field. *Prep. Working knowledge of C programming language.*

ECE 3392 Computer Architecture A (2QH)
Fall and Winter Quarters
ECE 3392 and ECE 3393 cover the same material with the same prerequisites as ECE 3391, but in two 2QH courses.

ECE 3393 Computer Architecture B (2QH)
Winter and Spring Quarters
Continuation of ECE 3392. *Prep. ECE 3392.*

ECE 3395 VLSI Design (4QH)
Fall Quarter
This course covers all aspects of VLSI design and engineering including: VLSI design methodology; MOS transistors and circuits; use CAD tools to create, extract, simulate and evaluate physical layouts; CMOS fabrication process; evaluation and optimization of circuit area, power consumption and propagation delay; use CAD tools to design CMOS systems with standard cells; design and evaluate system clocking; study the characteristics and limitations of CAD tools such as simulation, placement and routing; study VLSI testing, fault models, test vector generation and design for testability; design projects going through a complete VLSI design cycle; a research project targeting a specific area of VLSI engineering. *Prep. ECE 3101 and ECE 3103 or equivalent.*

ECE 3396 VLSI Design A (2QH)
Fall Quarter
ECE 3396 and ECE 3397 cover the same material with the same prerequisites as ECE 3395, but in two 2QH courses.

ECE 3397 VLSI Design B (2QH)
Winter Quarter
Continuation of ECE 3396. *Prep. ECE 3396.*

ECE 3398 VLSI Architectures (4QH)
Winter Quarter
This course augments the physical level VLSI design knowledge built in ECE 3395 by studying how to take advantage of VLSI technologies. Two architectural level design projects provide students with the opportunity to go through the design process of VLSI architectures. Prior project examples include the design and evaluation of FPGAs, application specific processors, and microprocessors. Performance and cost tradeoffs and decision making are specifically emphasized in these projects. Lectures provide theories and discussions to support these two design projects which include a brief review of VLSI design methodology; pipelining and parallel processing in VLSI processors; interconnection between VLSI processing units; VLSI oriented algorithms and applications; VLSI architecture synthesis; special VLSI architectures such as synchronous and asynchronous processor arrays and massively parallel fine-grained processor arrays; reconfigurable VLSI architectures. *Prep. ECE 3395.*

ECE 3399 VLSI Architectures A (2QH)
Winter Quarter
ECE 3399 and ECE 3400 cover the same material with the same prerequisites as ECE 3398, but in two 2QH courses. *Prep. ECE 3395.*

ECE 3400 VLSI Architectures B (2QH)
Spring Quarter
Continuation of ECE 3399. *Prep. ECE 3399.*

ECE 3401 Digital Systems Design with Hardware Description Languages (4QH)
Spring Quarter
This course covers design, simulation, modeling, and implementation of complex digital systems using high level computer hardware description languages (HDL). It begins with a description of digital system design hierarchy, and abstraction. Next a brief overview of available design tools and simulation programs will be given. HDLs, with emphasis on VHDL and AHPL will then be introduced. Using these languages for design and verification of digital systems at different levels of abstraction will be studied. Students will use VHDL software for design and simulation of large digital circuits. Silicon compilation, computer-aided design and automatic generation of hardware will also be addressed. *Prep. ECE 3391.*

ECE 3402 Digital Systems Design with Hardware Description Languages - A (2QH)
Fall Quarter
ECE 3402 and ECE 3403 cover the same material with the same prerequisites as ECE 3401, but in two 2QH courses. *Prep. ECE 3391.*

ECE 3403 Digital Systems Design with Hardware Description Languages - B (2QH)
Winter Quarter
Continuation of ECE 3402. *Prep. ECE 3402.*

ECE 3412 Power Systems Planning (4QH)
Spring Quarter
Engineering and economic considerations underlying the planning and development of modern interconnected power systems. Consideration of overall planning strategies involved in economic comparison of alternative development schemes. *Prep. ECE 3120.*

ECE 3415 Power Systems Protection (2QH)
Winter Quarter
Consideration of protection applied to generation, transmission, and distribution. Investigation of the characteristics and operating principles of various methods of protective relaying; analysis of current techniques pertaining to system protection. *Prep. ECE 3303.*

ECE 3416 Electromagnetic Power System Transients (2QH)
Fall Quarter
Transients in power systems due to system switching, lightning, or faults. Traveling-wave phenomena; insulation coordination; overvoltages due to disturbances on the system; surge protection. *Prep. ECE 3303.*

ECE 3417 Analysis of Equipment Failure (2QH)
Fall Quarter
Predicting the failure rate for equipment with little or no failure history will be illustrated using Bayesian Analysis which combines the meager failure data with a model for the failure process, to produce results much better than that obtained from Classical Probability Analysis. All results will be shown as probability histograms so that the uncertainty is explicit thus providing the decision maker with the actual odds of either making or losing money on a proposed availability improvement program. *Prep. Admission to Graduate School.*

ECE 3423 Special Topics in Power (2QH)
Spring Quarter
Directed reading and discussion of topics of special interest in the power field. Series of lectures by guest speakers from industry on topics of particular interest to the power student. *Prep. Permission of instructor.*

ECE 3424 Electromechanical Power System Dynamics (2QH)
Spring Quarter
Transient system models; small and large scale oscillations; solution of swing equation for single and multi-generator cases; load frequency and voltage controllers and transient stability. *Prep. ECE 3303.*

ECE 3429 Electric Power Transmission (4QH)
ECE 3429 covers the same material as ECE 3430 and ECE 3431 in 4 quarter hours. *Prep. ECE 3303.*

ECE 3430 Electric Power Transmission 1 (2QH)
Fall Quarter
Elements in the design of AC overhead transmission lines; thermal limitation, series and shunt compensation, environmental effects; consideration of transposition, induced effects, and insulation level. Underground alternatives to overhead lines. Elements of distribution. *Prep. ECE 3303.*

ECE 3431 Electric Power Transmission 2 (2QH)
Winter Quarter
Fundamental concepts of high voltage DC power transmission; rectifier and inverter performance; regulation; protection; reactive power and filter requirements; practical arrangement of DC lines; the impact of a DC line on overall power system operation. *Prep. ECE 3303.*

ECE 3432 Power Systems Operation and Control (4QH)
As Announced
The first part of the course covers the classical study of steady states in power systems and the solution of some voltage stability problems associated with them of very recent vintage. The goal is to present problem formulations and solutions to problems of load flow with several modifications, namely frequency deviations and voltage-sensitive loads. The second part of the course covers modeling, analysis and controller design for electromechanical transients in power systems (load variations, frequency, and power transmission dynamics). *Prep. ECE 3241.*

ECE 3433 Power Electronics (4QH)
As Announced
The first part of the course emphasizes understanding and modeling of power electronic circuits, and provides background for engineering evaluation of power converters. The second part of the course covers dynamics and control of this class of systems, enabling students to design controllers for a variety of power converters and motion control systems. The course is designed for students with primary interest in power conditioning, control applications and electronic circuits, but it may prove useful for designers of high-performance computers and other electronic systems in which the role of power supplies has to be adequately assessed. *Prep. Undergraduate course in Control Systems or ECE 3381.*

ECE 3454 Graph Theory (2QH)
Spring Quarter
Fundamentals of graph theory, including blocks, trees, connectivity, partitions, traversability, line graphs, factorization, coverings, planarity, matrices, digraphs, and enumeration problems. Selected applications of graph theory in such fields as network theory, switching theory, and computer science. *Prep. ECE 3211.*

ECE 3460 Special Topics in Computer Engineering (2QH)
Spring Quarter
Aspects of computer engineering not covered in other courses. The subject matter may change from year to year. *Prep. Permission of instructor.*

ECE 3463 Robot Vision and Sensors (4QH)
Winter Quarter
Methods of acquisition, representation and processing of real world information for robot control. A major portion of the course focuses on the different aspects of robot vision. Topics include: projection, lens distortion, image noise reduction, texture, edge-based systems, region-based systems, Hough space, matched filtering, object modeling, stereo vision, motion, and optical flow. Robot sensors covers a variety of sensor types including force/torque, proximity, and tactile sensors. *Prep. ECE 3466.*

ECE 3464 Robot Vision and Sensors A (2QH)
Winter Quarter
ECE 3464 and ECE 3465 cover the same material with the same prerequisites as ECE 3463, but in two 2QH courses.

ECE 3465 Robot Vision and Sensors B (2QH)
Spring Quarter
Continuation of ECE 3464. *Prep. ECE 3464.*

ECE 3466 Robotics and Automation Systems (4QH)
Fall Quarter
Methods of operation of general purpose and industrial manipulator systems; Kinematic and dynamic models of mechanical arms; joint solutions and motion characteristics; trajectory planning; arm control through coordinate transformations; classical feedback methods and modern closed-loop control techniques; real-time control of robotic systems. *Prep. ECE 3221.*

ECE 3467 Robotics and Automation Systems A (2QH)
Fall Quarter
ECE 3467 and ECE 3468 cover the same material with the same prerequisites as ECE 3466, but in two 2QH courses.

ECE 3468 Robotics and Automation Systems B (2QH)
Winter Quarter
Continuation of ECE 3467. *Prep. ECE 3467.*

ECE 3469 Fault-Tolerant Computers (4QH)
Spring Quarter
The course objective is to overview fault-tolerant computing, the design and evaluation of dependable systems, and also to provide a base for research in fault-tolerant systems. Quantitative evaluation and modeling provide the foundation for study of fault avoidance, fault detection, and fault removal from the component level to the system level. Contemporary and historical architectures are analyzed. Software evaluation tools are available for the class to explore fault-tolerant design spaces. *Prep. ECE 3391.*

ECE 3470 Fault-Tolerant Computers A (2QH)
Winter Quarter
ECE 3470 and ECE 3471 cover the same material with the same prerequisites as ECE 3469, but in two 2QH courses.

ECE 3471 Fault-Tolerant Computers B (2QH)
Spring Quarter
Continuation of ECE 3470. *Prep. ECE 3470.*

ECE 3472 Special Topics in Robotics (4QH)
Spring Quarter
This course focuses on the many aspects of building real world intelligent robot systems. Intelligent robots are composed of sensing modules, reasoning modules, and action modules. This course focuses on the integration of sensing, reasoning, and action to build real-world intelligent robot systems. Topics include software control architectures, world modeling, sensing, trajectory planning, sensor fusion, reasoning, and robot hardware requirements. *Prep. ECE 3463 and ECE 3466.*

ECE 3473 Parallel Architectures for High Performance Computing (4QH)
This course is concerned about how the concurrency that is inherently present in numerical computations can be exploited for high performance in multi-computer networks and application-specific processor architectures. We start from the basics by introducing: different models of parallel computation, practical network architectures (ring, mesh, hypercube), message routing mechanisms, coordination and communication primitives (one-to-all, all-to-all, broadcasting), parallel and distributed systems performance and scalability evaluation methods. Then we discuss how a sequential nested-loops algorithm can be transformed systematically into a parallel computational structure, so that it can be realized either in hardware (using a domain-specific architecture) or in software (using a network of distributed general purpose computers). Numerical algorithms are used to highlight the key issues involved in this mapping. High performance scalable parallelization strategies for computationally intensive operations, such as dense and sparse linear system solvers,

multidimensional data transforms, neural network simulators etc., often encountered in scientific, and multimedia applications are among the case studies analyzed in detail.

ECE 3476 Special Topics in Fault-Tolerant Computing (4QH)
Winter Quarter

Fault tolerant VLSI/WSI processor arrays: fault and error models for VLSI, reconfiguration techniques for run-time fault tolerance, graceful degradation, transient fault recovery, time redundancy, fabrication and compile time array restructuring for yield enhancement in wafer scale integration arrays. Fault tolerant communication structures: reliable shared memory and message passing mechanisms, fault tolerant loops, trees, hypercubes, etc., dynamically reconfigurable networks. System level diagnosis, diagnosability analysis, the PMC model, distributed diagnosis. Software fault tolerance, N-version programming, recovery blocks. *Prep. ECE 3469 or permission of instructor.*

ECE 3477 Testing and Design for Testability (4QH)
Fall Quarter

This course encompasses the theoretical and practical aspects of digital systems testing and the design of easily testable circuits. Major topics for the course include defect and fault models, test generation for combinational and sequential circuits, testing measures and costs, functional and parametric test methods, design for testability, built-in self test, and concurrent testing. The objective of the course is to provide the foundations for developing test methods for digital systems and to provide the techniques necessary to practice design for testability. *Prep. ECE 3395.*

ECE 3480 Distributed Systems (4QH)
Spring Quarter

This course covers fundamentals of distributed systems, distributed computing models, client-server computing, remote procedure calls, distributed file and directory services, distributed systems design and implementation issues, reliability and availability, security, overview of computer networks, and case studies in distributed systems. *Prep. Undergraduate course in Operating Systems.*

ECE 3483 Multiprocessor Architectures (4QH)
Fall Quarter

This course presents the issues related to designing and programming tightly-coupled shared-memory multiprocessor systems. The course will cover the issues of memory structure, snoopy and directory-based caching, memory consistency protocols, cache coherency protocols, processor interconnect strategies, and multiprocessor scalability. Issues related to program execution of real applications on a multiprocessor system will be covered, including synchronization primitives, task scheduling, and memory allocation. *Prep. Intro. course in computer architecture.*

ECE 3484 Combinatorial Optimization (4QH)
As Announced

An introduction to combinatorial optimization, an emerging field that combines techniques from applied mathematics, operations research and computer science to solve optimization problems over discrete structures. Emphasizes problems that arise in the areas of Electrical and Computer Engineering, including (but not limited to) VLSI, computer aided design, parallel computing, computer architecture, and high performance compiling. Covers the foundations of algorithm analysis, including asymptotic notation and complexity theory, and a range of optimization techniques, including divide and conquer, local optimization, dynamic programming, branch and bound, simulated annealing, genetic algorithms, approximation algorithms, integer and linear programming, matroid theory, and greedy algorithms. Considers the efficient generation of optimal solutions, the development and evaluation of heuristics, and the computation of tight upper and lower bounds. *Prep. Admission to the Graduate School.*

ECE 3485 Digital Hardware Synthesis (4QH)
As Announced

Techniques and tools for the automatic synthesis of digital systems. The course will focus on algorithms for translating a high level specification into an implementation. Topics covered will include a brief introduction to hardware description languages (HDL), automatic translation of the HDL to an intermediate format, architectural synthesis of the register transfer level implementation, automatic state machine synthesis and logic synthesis. Students will complete a research project in the automatic synthesis of digital designs. *Prep. C programming language, undergraduate level digital design and VLSI design.*

ECE 3497 Statistical Signal Processing (4QH)
Spring Quarter

Introduction to Statistical Signal Processing; optimum filtering: principle of orthogonality, spectral factorization and the innovations process, Weiner and Kalman filters: Linear Prediction and Autoregressive Models: Gram-Schmidt orthogonalization and

triangular matrix factorization, autoregressive model matching and the Yule-Walker equations, Order-Recursive Estimation: forward and backward prediction, lattice filter configuration, the Levinson and Schur algorithms, fast triangular factorization; Applications to adaptive arrays, echo cancellation, equalization, spectrum estimation, system identification, adaptive control, and speech analysis and synthesis; Estimation of Signal Statistics: autocorrelation estimates and their statistical properties, the deterministic least-squares approach, fundamentals of spectrum estimation, introduction to nonstationary spectrum analysis and estimation. *Prep. ECE 3241 and ECE 3321.*

ECE 3498 Statistical Signal Processing A (2QH)
Fall Quarter

ECE 3498 and ECE 3499 cover the same material with the same prerequisites as ECE 3497, but in two 2QH courses. *Prep. ECE 3321 and ECE 3241.*

ECE 3499 Statistical Signal Processing B (2QH)
Winter Quarter

Continuation of ECE 3498. *Prep. ECE 3498.*

ECE 3500 Auditory Signal Processing (4QH)
Fall Quarter, As Announced

This course provides engineers interested in the processing and production of audio signals with knowledge of how sounds are processed and perceived in the auditory system by exploring physiological and psychological acoustics. Special emphasis is placed on mathematical models of the auditory system. Topics covered include: properties of acoustical stimuli; anatomy and physiology of the auditory system; electrical recordings from the auditory system; methods of psychophysical measurements; absolute thresholds; temporal integration; masking and auditory frequency analysis; signal detection theory and models of masking; frequency and intensity discrimination; experiments and models on temporal processing; loudness; Zwicker's loudness summation model; pitch perception; binaural hearing; other perceptual continua; timbre, roughness, noisiness, and annoyance. After completing the course, students will have a thorough understanding of the auditory processes that govern perception of sounds and are fundamental to our ability to understand speech. *Prep. ECE 3241 or equivalent.*

ECE 3502 Special Topics in Digital Signal Processing - Fast Algorithms (2QH)
Fall Quarter

Fast algorithms for implementation of digital filters and discrete Fourier transforms: FFT, convolution algorithm, Number Theoretic Transforms (NTT), filtering computation, and polynomial transforms. *Prep. ECE 3321.*

ECE 3505 Digital Image Processing (4QH)
Spring Quarter

Topics include: generation of digital image from the source, image digitizers and display devices, image transforms, enhancement techniques such as histogram, equalization, edge sharpening etc.; restoration by Wiener and Kalman filters, image coding using run length coding, DPCM, transform coding and feature analysis. *Prep. ECE 332l.*

ECE 3506 Digital Image Processing A (2QH)
Fall Quarter

ECE 3506 and ECE 3507 cover the same material with the same prerequisites as ECE 3505, but in two 2QH courses.

ECE 3507 Digital Image Processing B (2QH)
Winter Quarter

Continuation of ECE 3506. *Prep. ECE 3506.*

ECE 3508 Modern Spectral Analysis (4QH)
Fall Quarter

This course starts with a description of the problem of estimating spectra from finite records of noisy data and a review of applications including biomedicine, geophysics, speech, non-destructive testing, sonar and radar, etc. It then explores many of the common power spectrum estimation algorithms, including both conventional and modern techniques. Emphasis is put on the advantages and limitations of conventional, Capon's, maximum entropy, parametric (AR, MA, and ARMA) and harmonic decomposition (Prony, Pisarenko, SVD) methods, in terms of accuracy (bias), reliability (variance) and other important criteria. Extensions to multi-channel and multi-dimensional data will be discussed, as well as a brief introduction to the array processing problem from a spectrum estimation perspective. The second half of the course will deal with higher order and non-stationary spectrum estimation, including both conventional and parametric higher order methods and sliding window (short-time Fourier transform and model-based), adaptive, time-frequency, and wavelet techniques for the non-stationary problem. *Prep. ECE 3241 and ECE 3321. Recommend ECE 3497.*

ECE 3509 Modern Spectral Analysis A (2QH)
Fall Quarter

ECE 3509 and ECE 3510 cover the same material with the same prerequisites as ECE 3508, but in two

2QH courses. *Prep. ECE 3321.*

ECE 3510 Modern Spectral Analysis B (2QH)
Winter Quarter
Continuation of ECE 3509. *Prep. ECE 3509.*

ECE 3511 Data Communications Networks (4QH)
Spring Quarter
Data networks fundamentals and layering; data link control layer; elements of queueing theory; networks with multi-access channels; local and metropolitan area networks: network layer (routing and flow control); performance evaluation. *Prep. ECE 3241.*

ECE 3512 Data Communications Networks A (2QH)
Winter Quarter
ECE 3512 and ECE 3513 cover the same material with the same prerequisites as ECE 3511, but in two 2QH courses.

ECE 3513 Data Communications Networks B (2QH)
Spring Quarter
Continuation of ECE 3512. *Prep. ECE 3512.*

ECE 3514 Error Correcting Codes (4QH)
Spring Quarter
Error correcting codes and their decoding techniques which show promise for applications in digital communication, control and computer systems. Emphasis is placed on the linear block codes based on algebraic structures; cyclic codes for random error correction (B-C-H codes) and burst error correction. Convolutional codes and decoding including the Viterbi algorithm, arithmetic codes. Combination of codes. Coding for ranging and synchronization. *Prep. ECE 3211.*

ECE 3515 Error Correcting Codes A (2QH)
Winter Quarter
ECE 3515 and ECE 3516 cover the same material with the same prerequisites as ECE 3514, but in two 2QH courses.

ECE 3516 Error Correcting Codes B (2QH)
Spring Quarter
Continuation of ECE 3515. *Prep. ECE 3515.*

ECE 3520 Special Topics in Communication Theory (2QH)
Spring Quarter
Current aspects of communication theory not covered in previous courses. Subject matter may change from year to year. *Prep. ECE 324l and ECE 335l.*

ECE 3526 Nonlinear Systems (4QH)
Fall Quarter, As Announced
Operators and functionals; The Volterra series representation of nonlinear systems; System Transforms; application of the Volterra theory to nonlinear system analysis: P-th order system inverses; the analysis of nonlinear feedback systems, circuits with nonlinear elements, and systems characterized by nonlinear differential equations. Introduction to orthogonal functionals. *Prep. ECE 3108 or equivalent.*

ECE 3527 Nonlinear Systems A (2QH)
Fall Quarter, As Announced
ECE 3527 and ECE 3528 cover the same material with the same prerequisites as ECE 3526, but in two 2QH courses.

ECE 3528 Nonlinear Systems B (2QH)
Winter Quarter, As Announced
Continuation of ECE 3527. *Prep. ECE 3527.*

ECE 3529 Nonlinear Systems 2 (2QH)
Spring Quarter, As Announced
Analysis of nonlinear systems with random inputs. The Wiener G-functionals, Nonlinear System identification. The Wiener model. The Gate functionals and their application to nonlinear system modeling and nonlinear filtering. Optimization of nonlinear models. *Prep. ECE 3526 and ECE 3241.*

ECE 3531 Adaptive Signal Processing (4QH)
Fall Quarter
Introduction to adaptive filtering: review of optimum filtering (Wiener-Kalman) and finite-order linear prediction; the stochastic gradient approach: Least-Mean-Squares (LMS) and normalized LMS adaptive FIR filters; Applications: equalization, noise cancellation, system identification, spectrum analysis, line enhancing, beamforming; the deterministic least-squares approach; Recursive Least Squares (RLS) adaptive filters: conventional RLS, QR-RLS; Comparative performance analysis of adaptive LMS and RLS filters: steady state error, tracking error, convergence rate and the role of orthogonalization, cost-performance trade-off; adaptive filter realizations that incorporate shift-invariance and orthogonalization: gradient and RLS lattice filters, RLS fast transversal filters (FTF); classification of adaptive (RLS)filters by: windowing-scheme, (prewindowed, sliding-window, unwindowed), architecture (triangular vs. linear, transversal vs. lattice), internal scaling (quotient, error-feedback, QR-based, etc.) and internal implementation; Multichannel adaptive filters; Finite precision effects in adaptive filters; introduction to adaptive IIR filters. *Prep. ECE 3497.*

ECE 3532 Adaptive Signal Processing A (2QH)
Fall Quarter
ECE 3532 and ECE 3533 cover the same material with the same prerequisites as ECE 3531, but in two 2QH courses. *Prep. ECE 3497.*

ECE 3533 Adaptive Signal Processing B (2QH)
Winter Quarter
Continuation of ECE 3532. *Prep. ECE 3532.*

ECE 3534 Digital Processing of Speech Signals (4QH)
Spring Quarter
Analysis and recognition of speech using computer techniques. Introduction to speech physiology, linguistics, phonetics, and acoustics. Models of speech production. Short-term processing of speech - temporal features, Fourier analysis, applications. Theory of linear predictive coding and applications. Homomorphic analysis of speech and applications. Speech and speaker recognition. *Prep. ECE 3321.*

ECE 3535 Digital Processing of Speech Signals A (2QH)
Fall Quarter
ECE 3535 and ECE 3536 cover the same material with the same prerequisites as ECE 3534, but in two 2QH courses. *Prep. ECE 3321.*

ECE 3536 Digital Processing of Speech Signals B (2QH)
Winter Quarter
Continuation of ECE 3535. *Prep. ECE 3535.*

ECE 3537 Multi-User Communication Systems (4QH)
Spring Quarter
Contention-free multiple-access techniques: frequency-division multiple-access (FDMA), time-division multiple-access (TDMA). Spread-spectrum multiple-access (SSMA) communications: Direct-sequence SSMA, frequency-hop SSMA, and hybrid SSMA systems. Communication networks: queuing theory, multiple-access with contention (ALOHA random-access and tree algorithms for random-access), network routing and flow control (quasi-static control versus dynamic control). An overview of the applications of multi-user communication systems: computer-communication networks, broadcast satellite systems, military communications, mobile radio communications, packet-radio communication networks, and fiber-optic local-area networks. *Prep. ECE 3351.*

ECE 3538 Multi-User Communication Systems A (2QH)
Winter Quarter
ECE 3538 and ECE 3539 cover the same material with the same prerequisites as ECE 3537, but in two 2QH courses.

ECE 3539 Multi-User Communication Systems B (2QH)
Spring Quarter
Continuation of ECE 3538. *Prep. ECE 3538.*

ECE 3540 Digital Control Systems (4QH)
Winter Quarter
Analysis of linear discrete-time dynamic systems; discretization of continuous systems; sampling and aliasing. Design of digital control systems using transform techniques by discrete equivalent and direct design methods; root locus, Bode and Nyquist diagrams and Nichols charts. Multivariant digital control using state-space methods; pole placement, observer, and regulator design. Controller implementation issues: digital filter realizations, nonlinear effects due to quantization, roundoff, deadband, limit cycles. Selection of the sampling rate. *Prep. ECE 3221 and ECE 338l.*

ECE 3541 Digital Control Systems A (2QH)
Fall Quarter
ECE 3541 and ECE 3542 cover the same material with the same prerequisites as ECE 3540, but in two 2QH courses.

ECE 3542 Digital Control Systems B (2QH)
Winter Quarter
Continuation of ECE 3541. *Prep. ECE 3541.*

ECE 3546 Advanced Topics in Stochastic Systems (4QH)
Winter Quarter
Current research topics in stochastic systems. Topics include polyspectra and higher order moments, parametric extrapolation, innovations, mean-square filtering and estimation, Monte Carlo methods, random number generation, entropy and coding. *Prep. ECE 3241.*

ECE 3547 Advanced Topics in Stochastic Systems A (2QH)
Winter Quarter
ECE 3547 and ECE 3548 cover the same material with the same prerequisites as ECE 3546, but in two 2QH courses.

ECE 3548 Advanced Topics in Stochastic Systems B (2QH)
Spring Quarter
Continuation of ECE 3547. *Prep. ECE 3547.*

ECE 3549 Multivariable Control Systems (4QH)
Spring Quarter
Mathematical preliminaries, polynomial and polynomial matrices; representations of linear multivariable system; matrix fraction description (MFD) and polynomial matrix description (PMD); responses of linear multivariable systems; controllability, observability and canonical forms; poles and zeros of multivariable systems; stability; realization problem; interaction control; state feedback and observer design; compensator design, stability and robustness; noninteraction control; frequency domain design techniques. *Prep. ECE 3221 and ECE 3381.*

ECE 3550 Multivariable Control Systems A (2QH)
Fall Quarter
ECE 3647 and ECE 3648 cover the same material with the same prerequisites as ECE 3646, but in two 2QH courses. *Prep. ECE 3321 and ECE 3381.*

ECE 3551 Multivariable Control Systems B (2QH)
Winter Quarter
Continuation of ECE 3647. *Prep. ECE 3647.*

ECE 3552 System Identification and Adaptive Control (4QH)
Fall Quarter
Identification is the process of mathematically modeling a system based on measurement data that may be limited or uncertain. Adaptive control, then, is the means whereby a system that is poorly modeled is controlled adequately. The purpose of the system identification portion of the course is to enhance the underlying basic ideas, which are essential for adaptive control. Particular emphasis is given to recursive approaches, such as recursive least square algorithm, where parameter estimates are updated in real-time. The adaptive control portion of the course covers simple adaptive systems, adaptive observers and adaptive control. Two major adaptive schemes, namely, Model Reference Adaptive Control (MRAC) and Self-Tuning Regulators (STR) are treated in detail. Fundamental issues such as stability of adaptive systems, convergence, persistent excitation, and robustness will be discussed. An important by-product of the course is that the students will identify several points of tangencies between two areas of control systems and signal processing. *Prep. ECE 3221 and ECE 3321.*

ECE 3553 Spread Spectrum Communication Systems (4QH)
As Announced
This course introduces the fundamental concepts of spread spectrum communication systems. The basic theory of direct sequence (PN) and frequency hopping (FH) spread spectrum techniques will be studied in detail. Some important topics such as code generation and signal acquisition will also be covered. Some of the major characteristics of fading channels will be included as a complementary major subtopic. The performance of uncoded and coded spread spectrum communications in the presence of interference, jamming, and fading environments will be given considerable attention. The low probability of interception/detection (LPI/LPD) characteristics of spread spectrum techniques in multi-user communication systems will be included as a major topic. Various practical applications of spread spectrum will be presented, including some recent satellite mobile radio system designs. *Prep. ECE 3351 or equivalent.*

ECE 3554 Advanced Topics in Communications (4QH)
As Announced
This course treats the design and performance analysis of modern digital communication techniques used in the realistic band-limited channels, including both the wired links, such as telephone and cable lines, and the wireless links, such as mobile radio channels. The following topics are treated in depth: 1) Signal design for band-limited channels according to Nyquist criteria, and optimum receiver design for intersymbol interference channels; 2) Equalization, including linear equalization, decision-feedback equalization, maximum-likelihood methods using the Viterbi algorithm, adaptive equalization and channel estimation, and blind equalization; 3) Multicarrier modulation methods or OFDM; 4) Spread-spectrum techniques, including direct-sequence and frequency-hopping for CDMA systems and for interference suppression; 5) Fading channel statistical characterization; and 6) Diversity techniques for fading channels, including spatial, frequency and time diversity, as well as multipath diversity through rake reception. The course is accompanied by a series of (Matlab) computer simulation exercises, which are used to substantiate the concepts studied in class, and are geared toward the development of each student's personalized communication system simulation toolbox. *Prep. ECE 3351.*

ECE 3555 Statistical Pattern Recognition and Neural Networks (4QH)
As Announced

Pattern recognition problems arise in many areas of practical importance such as character recognition, computer vision, biomedical pattern classification and speech recognition. In this course pattern recognition problems are approached from a statistical point of view. Also neural networks as means of pattern recognition are studied. The subjects covered include: Bayes decision theory, discriminant functions, supervised and unsupervised learning, nearest neighbor classifiers, perception training algorithm, speech recognition, neural network fundamentals, feedforward neural networks and the back propagation algorithm, feedback neural networks, stable states, associative memory, capacity of neural networks. *Prep. ECE 3241.*

ECE 3556 Special Topics in System Theory (4QH)
Spring Quarter

Current aspects of system theory not covered in previous courses. Subject matter may change from year to year. *Prep. ECE 3211 and ECE 3221.*

ECE 3557 Special Topics in Signal Processing (4QH)
Winter Quarter

Aspects of signal processing not covered in other courses. Topics may vary from year to year. *Prep. ECE 3321.*

ECE 3558 Digital Filter Banks and Wavelets (4QH)
As announced

This course develops the theory and applications of perfect reconstruction digital filter banks (PR filter banks) and continuous-time wavelet and wavepacket representations. The mathematical structure of the two disciplines are shown to be intimately related and the theory of both is developed both from a signal processing view point and an abstract mathematical view point. Applications that include signal processing and digital communications are examined in detail. Special emphasis is given to the multi-resolution analysis (MRA) of discrete and continuous-time signals and to applications that make use of this paradigm. *Prep. ECE 3321.*

ECE 3559 Wireless Communications (4QH)
As Announced

The course treats a diverse range of topics in wireless communications for applications such as cellular mobile radio, personal communication services (PCS) and wireless LANs (local area networks). Cellular system design, frequency reuse, channel assignment, handoff, power control, cell splitting, sectorization and system capacity. Radio propagation, path-loss models, log-normal shadowing, determination of coverage area, multipath and fading, statistical models for outdoor and indoor channels. Signal design principles: spectrum-efficient modulation methods (GMSK, $\pi/4$ QPSK), spread-spectrum modulation techniques (direct-sequence and frequency-hopping). Radio reception, receiver/transmitter architectures. Adaptive equalization (maximum-likelihood, linear and decision-feedback methods). Diversity techniques (selection, maximum ration combining, equal gain combining). Bit error rate and outage probability on fading channels. Multiple access for wireless systems: frequency, time, code and space division multiple access (FDMA, TDMA, CDMA, SDMA). Wireless networking (packet-reservation multiple access, switching, mobility management for PCS). Standards for wireless systems: AMPS, IS-54, IS-95 (U.S. digital cellular based on CDMA), GSM (Global System Mobile) and the PCS standards. Future (third generation) systems and the International Mobile Telecommunications (IMT-2000). *Prep. ECE 3351*

ECE 3560 Acoustics I (2QH)
Fall Quarter

The wave theory of sound. Radiation, reflection, and transmission phenomena. Distributed system analogies, and sound measurements. *Prep. ECE 3341.*

ECE 3561 Acoustics 2 (2QH)
Winter Quarter

Speech and hearing, microphones and loudspeakers, guided waves, room acoustics. Environmental acoustics. *Prep. ECE 3560.*

ECE 3562 Acoustics 3 (2QH)
Spring Quarter

Scattering and diffraction. Effects of viscosity and heat conduction. Finite amplitude and shock waves. Introduction to underwater sound. *Prep. ECE 3561.*

ECE 3563 Radar Systems 1 (4QH)
Spring Quarter

Emphasis on the systems aspects of radar engineering. Topics covered include basic theory of radar detection, measurement of range, angle, and Doppler shift; classes of radar systems; types of radar noise; components of a radar system; matched filters and correlation receivers as applied to radar systems; fundamental ideas of radar system analysis. In-depth study of search radar theory; maximum likelihood estimation approach to measurement of radar target parameters;

resolution and ambiguity functions applied to radar; radar parameter uncertainty principles. *Prep. ECE 3241.*

ECE 3564 Radar Systems 1-A (2QH)
Fall Quarter
ECE 3564 and ECE 3565 cover the same material with the same prerequisites as ECE 3563, but in two 2QH courses. *Prep. ECE 3241.*

ECE 3565 Radar Systems 1-B (2QH)
Winter Quarter
Continuation of ECE 3564. *Prep. ECE 3564.*

ECE 3566 Radar Systems 2 (2QH)
Spring Quarter
Advanced topics in radar systems engineering. Topics to be covered include: design considerations for multistatic radar systems, synthetic aperture radars; tracking systems; radar waveform synthesis; multi-function array radar techniques and selected topics in radar sensing techniques and devices. *Prep. ECE 3563 or ECE 3565.*

ECE 3567 Network Information Theory (4QH)
Fall Quarter
This course deals with the fundamental limits on information compression and transmission in multi-user communication network from an information theoretic point of view. Topics covered in this course include: basics of point-to-point information theory, conditional AEP, capacity of channels with feedback, joint coding of correlated sources, source coding with side information, data compression with side information, multiple access channels, feedback in multiple access channels, broadcast channels and superposition coding, two-way channels, the wiretap channel. *Prep. ECE 3241.*

ECE 3571 Fourier and Binary Optics (4QH)
Fall Quarter
This course covers the fundamentals of Fourier and binary optics from a theoretical and a practical standpoint: radiation as a wave, polarization of radiation, reflection and refraction at surfaces, optical diffraction, scalar wave equation; Helmholtz and Kirchoff integral theorems, Fresnel and Fraunhoffer diffraction, Green's theorem, interferometry; division of amplitude, division of wavefront, diffraction gratings, multi-layer filters, interferometric instrumentation, holography. Imaging properties of lenses and optical systems, coherent and incoherent imaging, Modulation Transfer Function, spatial filtering, diffraction-limited optical systems, surface design of binary optical elements, miniature and micro-optics, fabrication of diffraction-limited optics, applications of diffraction-limited optics. *Prep. ECE 3581 or ECE 3582.*

ECE 3572 Fourier and Binary Optics 1-A (2QH)
Winter Quarter
ECE 3572 and ECE 3573 cover the same material with the same prerequisites as ECE 3571, but in two 2QH courses. *Prep. ECE 3581 or ECE 3582.*

ECE 3573 Fourier and Binary Optics 1-B (2QH)
Spring Quarter
Continuation of ECE 3572. *Prep. ECE 3572.*

ECE 3574 Fourier Optics 2 (2QH)
Fall Quarter
Covers current topics of interest in Fourier optics and optical instrumentation. Application of coherence phenomena to optical instrumentation such as micro-densitometers, microscopes, viewers, cameras, spectraphotometric and interferometric instruments; applications of holography, optical data processing and computing, holographic memories, optical modulation, noise and its effects on data collection, synthetic aperture optics and medical application of laser optics. *Prep. ECE 3571 or ECE 3573.*

ECE 3575 Lasers (4QH)
As Announced
Introduction to basic principles of lasers. Models for the interaction of electromagnetic radiation and matter. Laser threshold and rate equations. Resonator theory; transverse and longitudinal modes, and Rigrod analysis. Homogeneous and inhomogeneous broadening. Q switching, cavity dumping, and mode locking. Specific laser types including gas, liquid, and solid. Applications of lasers and laser systems. *Prep. Admission to Graduate School.*

ECE 3576 Lasers 1 (2QH)
Fall Quarter
ECE 3576 and 3577 cover the same material as ECE 3575 but in two 2QH courses. *Prep. Admission to Graduate School.*

ECE 3577 Lasers 2 (2QH)
Winter Quarter
Continuation of ECE 3576. Prep. ECE 3576.

ECE 3578 Lasers 3 (2QH)
Spring Quarter
Applications of lasers and laser systems for a variety of engineering and basic science disciplines; specific laser optoelectronic devices. *Prep. ECE 3575 or ECE 3577.*

ECE 3579 Optoelectronics and Fiber Optics (2QH)
Winter Quarter
This course covers the fundamentals of the optoelectronic elements that interconnect to create a fiber optic system for communication and sensing; structure of single and multi-mode fibers, step and graded index fibers, modal theory of fiber propagation, ray theory of multi-mode fibers, fiber parameters, numerical aperture, Etendue, modal cutoff; couple mode theory; semiconductor physics, diode lasers and LED sources; photovoltaic and photoconductive detectors; coupling sources and detectors to optical fibers; noise in fiber optic systems; active and passive components, modulators, couplers; fiber interferometry; applications in communication and sensing. *Prep. ECE 3580.*

ECE 3580 Optics for Engineers I (2QH)
Spring Quarter
ECE 3580 and ECE 3581 cover the same material with the same prerequisites as ECE 3582 but in two 2QH courses. *Prep. Bachelor of Science Degree in Engineering or Physics.*

ECE 3581 Optics for Engineers 2 (2QH)
Fall Quarter
Continuation of ECE 3580. *Prep. ECE 3580.*

ECE 3582 Optics for Engineers (4QH)
Spring Quarter
This course is an introductory graduate course in optics, presenting the engineering concepts necessary to understand and evaluate electro-optical systems. It begins with a brief but rigorous treatment of geometric optics, including matrix methods, aberrations, pupils and windows, with practical example of optical instruments and electro-optical systems. Other topics include polarization, interference, diffraction, and optical properties of crystals, thin-films, optical resonators, guided waves, modulators and detectors. The concepts are presented with examples from modern optical systems such as LIDAR, fiber-optical sensors, rangefinders, infrared systems, and optical communication systems. *Prep. Bachelor of Science Degree in Engineering or Physics.*

ECE 3583 Optical Properties of Matter I (2QH)
Fall Quarter
ECE 3583 and ECE 3584 cover the same material with the same prerequisites as ECE 3597, but in two 2QH courses. *Prep. Bachelor of Science Degree in Engineering or Physics.*

ECE 3584 Optical Properties of Matter 2 (2QH)
Winter Quarter
Continuation of ECE 3583. *Prep. ECE 3583.*

ECE 3585 Optical Properties of Matter 3 (2QH)
Spring Quarter
Thin films and optical fibers multi-layer filters; dichroics; integrated optics. *Prep. ECE 3584.*

ECE 3586 Optical Detection (4QH)
Spring Quarter
The main emphasis of this course is on the detector as a critical component of an electro-optical system. Initial topics include descriptions of the different classes of detectors; imaging and non-imaging detectors, the scanning process, resolution and contrast, time and wavelength responses. These topics will be followed by a rigorous presentation of the mathematical basis of optical detection theory, including photon statistics, related noise issues (quantum noise, background noise) and system limits (NEP, D*). Applications will be presented in the form of system studies, including LIDAR, optical communication, low-light level television, thermal imaging, subnanosecond and heterodyne detection. *Prep. Bachelor of Science Degree in Engineering or Physics.*

ECE 3587 Optical Detection A (2QH)
Winter Quarter
ECE 3587 and 3588 cover the same material with the same prerequisites as ECE 3586, but in two 2QH courses. *Prep. Bachelor of Science Degree in Engineering or Physics.*

ECE 3588 Optical Detection B (2QH)
Spring Quarter
Continuation of ECE 3587. *Prep. ECE 3587.*

ECE 3589 Optical Storage and Display (2QH)
Fall Quarter
Survey of materials and methods for the storage and display of information. Topics included are: photographic film, holograms, storage tubes, magneto-optical films, photochromic materials, electro-optical crystals, evaporated thin films and liquid crystals. *Prep. Bachelor of Science Degree in Engineering or Physics.*

ECE 3590 Optical Instrumentation Design (2QH)
Fall Quarter
An introduction to the design of optical instrumentation. Principles and basic concepts of optical systems. In sequence the topics are: introduction, mechanical shock and vibration, kinematic designs; application of

third order aberrations, simple optical ray tracing, optical testing, tolerances, optical instrumentation, philosophy, functional design, design for quantity production, quality assurance, "special order" design, industrial design, examples and exercises. *Prep. Bachelor of Science Degree in Engineering or Physics.*

ECE 3591 Modern Spectroscopy (2QH)
Winter Quarter

This course addresses the optical instrumentation and applications of UV. Visible, and IR spectroscopy. Beginning with a historical review, it covers various instruments, their design and optimization. Models for understanding spectra of complex systems are developed, along with algorithms for processing spectral data. Practical examples are presented from chemistry, environmental remote sensing, and medical diagnosis. *Prep. ECE 3581.*

ECE 3593 Plasma Engineering (4QH)
Fall Quarter, As Announced

Overview of the basic principles and applications of plasma and gaseous discharges. The topics include gas kinetics, interaction of electrons and ions with static and rf fields as well as wave propagation in plasmas. Applications in material processing, space exploration and microwave devices will also be discussed. *Prep. ECE 3341.*

ECE 3594 Plasma Theory (4QH)
Spring Quarter, As Announced

Introduction to the basic theory of gaseous discharges. Fluid and kinetic description of collisionless and collisional plasmas with and without magnetic field effects. Emphasis will be placed on linear stability analysis, although nonlinear effects will also be discussed. *Prep. ECE 3341.*

ECE 3595 Plasma Theory A (2QH)
Winter Quarter, As Announced

ECE 3595 and ECE 3596 cover the same material with the same prerequisites as ECE 3594, but in two 2QH courses. *Prep. ECE 3341*

ECE 3596 Plasma Theory B (2QH)
Spring Quarter, As Announced

Continuation of ECE 3595. *Prep. ECE 3595.*

ECE 3597 Optical Properties of Matter (4QH)
Fall Quarter

This course will present the formal mathematical treatment of classical crystal optics, including dispersion, polarization, birefringence, metal optics, and the optics of thin films. Special emphasis will be on the interaction of electromagnetic waves and the crystal lattice. Next, classical crystal optics will be extended to non-linear effects observed with very intense electric and magnetic fields. Applications of non-linear optics, such as second and third harmonic generation, optical mixing, optical parametric oscillation, multiple photon interaction, linear and non-linear scattering will be presented. Finally, various topics in linear and non-linear optics will be applied in areas such as birefringent filters, second-harmonic generators, optical parametric oscillators and acousto-optical beam deflectors. *Prep. Bachelor of Science Degree in Engineering or Physics.*

ECE 3598 Remote Sensing (4QH)
Spring Quarter

Introduction to the theory, instruments, and techniques for remote sensing of the earth. Topics include: fundamental properties of electromagnetic radiation; matter-energy interaction in the optical and microwave regions; optical imaging systems; synthetic aperture radar and side-looking airborne radar imaging systems; radar polarimetry; microwave scatterometry and radiometry; system considerations such as temporal and spatial resolution, operating frequency and bandwidth, calibration, measurement precision, and accuracy; data acquisition and storage: models and techniques for retrieving geophysical parameters from remotely sensed data; survey of current and planned airborne and spaceborne remote sensing systems and application of these sensors to measuring geophysical phenomena and monitoring global change. *Prep. ECE 3341 and ECE 3241 or equivalent.*

ECE 3599 IR Imaging (2QH)
As Announced

This course covers the basic concepts necessary for understanding, designing, and evaluating electro-optical systems, including modern infra-red technology. Special emphasis will be given to considering the system as a whole, including radiation sources, the optical collection system, and the detection process. Performance characteristics and system limitations will be derived for a variety of imaging and non-imaging systems, as well as laser devices. Systems to be analyzed may include standard commercial television, night vision devices, laser rangers, thermal imagers, satellite imagers (LANDSAT, SPOT), optical communications and guidance systems. *Prep. Admission to Graduate School.*

ECE 3600 Microwave Properties of Materials (4QH)
Fall Quarter

General dielectric and magnetic properties of materials; Tensor properties of dielectric and magnetic materials; Special microwave properties of thin film materials; Experimental techniques developed in the

characterization of microwave materials. *Prep. ECE 3102 and ME 1386 or equivalent.*

ECE 3601 Microwave Properties of Materials A (2QH)
Fall Quarter
ECE 3601 and ECE 3602 cover the same materials with the same prerequisites as ECE 3600, but in two 2QH courses. *Prep. ECE 3102 and ME 1386 or equivalent.*

ECE 3602 Microwave Properties of Materials B (2QH)
Winter Quarter
Continuation of ECE 3601. *Prep. ECE 3601.*

ECE 3603 Propagation in Artificial Structures (4QH)
Fall Quarter, As Announced
Effective dielectric and permeability constants in composite materials at high frequencies; Electromagnetic wave propagation in electrical and magnetic anisotropic media; magneto-static and magneto-elastic wave propagation in single layer; Electromagnetic wave propagation in multi-layers. *Prep. ECE 3102 or equivalent.*

ECE 3604 Propagation in Artificial Structures A (2QH)
Winter Quarter, As Announced
ECE 3604 and ECE 3605 cover the same material with same prerequisites as ECE 3603, but in two 2QH courses. *Prep. ECE 3102 or equivalent.*

ECE 3605 Propagation of Artificial Structures B (2QH)
Spring Quarter, As Announced
Continuation of ECE 3604. *Prep. ECE 3604.*

ECE 3606 Applications of Plasma Engineering (4QH)
Spring Quarter, As Announced
Basic operational principles of microwave electron devices, the theory of electric domain formation, free electron and gaseous lasers, particle beam accelerators and radiation sources. Particular topics include both classical microwave devices such as magnetrons, gyrotrons and crossed-field amplifiers, and solid state devices such as Gunn diodes and Impatt diodes. *Prep. ECE 3593.*

ECE 3607 Applications of Plasma Engineering A (2QH)
Winter Quarter, As Announced
ECE 3607 and ECE 3608 cover the same material with the same prerequisites as ECE 3606, but in two 2QH courses. *Prep. ECE 3593.*

ECE 3608 Applications of Plasma Engineering B (2QH)
Spring Quarter, As Announced
Continuation of ECE 3607. *Prep. ECE 3607.*

ECE 3609 Special Topics in Electromagnetics (4QH)
As Announced
The course will concentrate on inverse problems associated with multidimensional wave equations such as the Schrodinger equation, Maxwell equations and the elastic wave equation. The theory will be developed using both the operator formalism employed in electromagnetic and acoustic scattering theory. Specific topics covered in the course include the inverse Sturm Liouville problem, the deterministic and random inverse source problems, inverse diffraction, and the multidimensional inverse scattering problem. The theoretical development will be accompanied by a thorough review of current applications of inverse scattering theory which include structure determination using X-rays and electron probes, S-ray holography, geophysical prospecting and remote sensing, coherent radar imaging, and diffraction tomography. *Prep. ECE 3231; permission of instructor.*

ECE 3610 Electronics of Analog Signal Processing (4QH)
Spring Quarter, As Announced
Analog signal acquisition and processing utilizing state of the art devices and circuit techniques such as adaptive filters in sampled data systems, CZTs for spectral analysis, correlated double sampling for improved S/N ratios and solid state imaging systems. Linear and nonlinear processing with MOS, bipolar and CTDs such as CCDs and SAWs. Attention given to analog vs. digital approaches for implementation of similar applications, i.e., bandwidth requirements, throughput, accuracy, cost, etc. *Prep. ECE 3331 and ECE 3384.*

ECE 3611 Electronics of Analog Signal Processing A (2QH)
Fall Quarter, As Announced
ECE 3611 and ECE 3612 cover the same material with the same prerequisites as ECE 3610, but in two 2QH courses.

ECE 3612 Electronics of Analog Signal Processing B (2QH)
Winter Quarter, As Announced
Continuation of ECE 3611. *Prep. ECE 3611.*

ECE 3613 Solid State Microwave Circuits (4QH)
Spring Quarter, As Announced
Design and analysis of solid state microwave circuits. Based on scattering parameters, design procedures for amplifiers are developed taking into consideration stability, power gain, noise, bandwidth and high power performance. Design of negative resistance oscillators based on small signal and large signal scattering parameters. The principles of design and operation of detectors and mixers using device non-linearity. Microwave control circuits including switches, phase shifters, limiters and attenuators. Circuits to produce frequency multiplication and division. Introduction to computer-aided design adoptimization using Touchstone and Libra software. *Prep. ECE 3101 or equivalent.*

ECE 3614 Solid State Microwave Circuits A (2QH)
Fall Quarter
ECE 3614 and ECE 3615 cover the same material with the same prerequisites as ECE 3613, but in two 2QH courses. *Prep. ECE 3101 or equivalent.*

ECE 3615 Solid State Microwave Circuits B (2QH)
Winter Quarter
Continuation of ECE 3614. *Prep. ECE 3614.*

ECE 3616 Active Network Synthesis and Design (4QH)
Fall Quarter, As Announced
Multiloop feedback techniques are developed and applied to integrated circuit designs such as three-stage Op-Amp realizations and minimum sensitivity amplifiers. Application of these circuits in continuous-time and switched-capacitor filters are treated. Single-active biquadratic filter sections of Sallen and Key and Friend-Delyannis are developed. Multiloop and multiple-active element realizations such as the generalized impedance converter (GIC), frequency-dependent negative resistance (FDNR), follow-the-leader (FLF) and leap-frog (LF) structures are discussed. Design considerations include sensitivity, yield factors, gain-bandwidth product and the approximation problem. MOS switched-capacitor realizations of basic filter structures are developed. *Prep. ECE 3331.*

ECE 3617 Active Network Synthesis and Design A (2QH)
Fall Quarter, As Announced
ECE 3617 and ECE 3618 cover the same material with the same prerequisites as ECE 3616, but in two 2QH courses. *Prep. ECE 3331.*

ECE 3618 Active Network Synthesis and Design B (2QH)
Winter Quarter, As Announced
Continuation of ECE 3617. *Prep. ECE 3617.*

ECE 3626 Integrated Circuits Fabrication 1 (4QH)
Spring Quarter
Overview of the basic techniques and processes employed in the fabrication of modern integrated circuits. Concentrates on the principles underlying the processes that are used to fabricate integrated circuits. Particular emphasis is placed on the processes that are most critical in the evolution of the technology; lithography and multilevel metallization. Discussions of yield and process integration for CMOS IC's and semiconductor memories conclude the course. *Prep. ECE 3384 or equivalent.*

ECE 3627 Integrated Circuits Fabrication Processes 1-A (2QH)
Winter Quarter
ECE 3627 and ECE 3628 cover the same material with the same prerequisites as ECE 3626, but in two 2QH courses. *Prep. ECE 3384.*

ECE 3628 Integrated Circuits Fabrication Processes 1-B (2QH)
Spring Quarter
Continuation of ECE 3627. *Prep. ECE 3627.*

ECE 3629 Integrated Circuit Fabrication Processes: Plasma Processing (4QH)
Fall Quarter, Odd-numbered years
It is estimated that between 1/3 and 1/2 of the steps used to manufacture a modern integrated circuit involve gas plasmas. This course covers the fundamental behavior of low temperature plasmas used for integrated circuit fabrication. Plasma physics, plasma chemistry, and plasma reactor design will be discussed. These topics will be combined to develop a working knowledge of plasma etching, thin film deposition, and ion implantation. The course material will be covered at an introductory graduate level such that an undergraduate understanding of physics, chemistry, and electrical circuits serves as sufficient preparation. *Prep. Admission to Graduate School.*

ECE 3630 Integrated Circuits Fabrication Processes 2-A: Plasma Processing (2QH)
Fall Quarter, As Announced
ECE 3630 and ECE 3631 cover the same material with the same prerequisites as ECE 3629, but in two 2QH courses. *Prep. Admission to Graduate School.*

ECE 3631 Integrated Circuit Fabrication Processes 2-B: Plasma Processing (2QH)
Winter Quarter, As Announced
Continuation of ECE 3630. *Prep. ECE 3630.*

ECE 3632 Design and Analysis of Digital Integrated Circuits (4QH)
Winter Quarter, As Announced
The analysis and design of basic digital-integrated-circuit logic families are treated. Bipolar circuits, including advanced-Schottky TTL, emitter-coupled logic (ECL). Double-buffered CMOS and NMOS logic gates, including dynamic logic circuits such as domino logic, are covered. Memory cells and basic cells in logic arrays are treated. Design considerations include propagation delay, switching speed, fan-out and the effect of parasitics. Design techniques are correlated with computer simulations. *Prep. ECE 3101 or equivalent.*

ECE 3633 Design and Analysis of Digital Integrated Circuits A (2QH)
Winter Quarter, As Announced
ECE 3633 and ECE 3634 cover the same material with the same prerequisites as ECE 3632, but in two 2QH courses. *Prep. ECE 3101 or equivalent.*

ECE 3634 Design and Analysis of Digital Integrated Circuits B (2QH)
Spring Quarter, As Announced
Continuation of ECE 3633. *Prep. ECE 3633.*

ECE 3635 Antennas and Radiation (4QH)
Spring Quarter
Presentation of the fundamental theory and properties of antennas: equivalence, reciprocity, uniqueness, Huygens principle, antenna impedance, diffraction; linear, loop, array, and aperture antennas, including horns, reflectors, lenses, and microstrip; transmitting and receiving antennas and transmission formulas, numerical antenna analysis methods. *Prep. ECE 3341, ECE 3344.*

ECE 3636 Antennas and Radiation A (2QH)
Fall Quarter
ECE 3636 and ECE 3637 cover the same material with the same prerequisites as ECE 3635, but in two 2QH courses. *Prep. ECE 3341 and ECE 3344.*

ECE 3637 Antennas and Radiation B (2QH)
Winter Quarter
Continuation of ECE 3636. *Prep. ECE 3636.*

ECE 3638 Microwave Electron Devices (4QH)
Spring Quarter, As Announced
The fundamental principles and operation of the principle types of conventional (linear-beam and crossed-field) and novel (maser effect) devices will be presented. Interactions of non-relativistic and relativistic electron beams with electromagnetic fields. Linear-beam tubes (klystron, traveling wave tube, backward-wave amplifier and oscillator etc.) crossed-field tubes (magnetron, forward and backward cross-field amplifier, high-gain CFA, etc.). Maser-effect devices (cyclotron maser, gyrotron). *Prep. ECE 3341.*

ECE 3639 Microwave Electron Devices A (2QH)
Winter Quarter
ECE 3639 and ECE 3640 cover the same material with the same prerequisites as ECE 3638, but in two 2QH courses. *Prep. ECE 3341.*

ECE 3640 Microwave Electron Devices B (2QH)
Spring Quarter
Continuation of ECE 3639. *Prep. ECE 3639.*

ECE 3641 High Speed/High Frequency Solid State Devices (4QH)
As Announced
Schottky barrier diode, Gunn diode, p-i-n diode, IMPATT diode, MESFET, heterostructures; heterojunction bipolar transistor (HBT), high electron mobility transistor (HEMT), resonant tunnelling diode (RTD); photonic devices including light emitting diodes and lasers, noise properties. *Prep. ECE 3384.*

ECE 3642 Microelectromechanical Systems (MEMS) (4QH)
As Announced
This course covers the Microelectromechanical Systems (MEMS) field at the graduate level. Tensor physics will be reviewed and used to describe physical properties of importance to sensors and actuators including; stress, strain, piezoresistivity, and elasticity. Students will examine methods which are used to predict the deflections of common mechanical structures used in MEMS. The course then covers both bulk and surface micromachining, including techniques for measuring properties of thin films including built-in strain, strain gradients and Young's modulus. The course concludes with a discussion of analysis and modeling of MEMS systems. Stability and noise will be covered. *Prep. Admission to Graduate School.*

ECE 3644 Passive Microwave Circuits (4QH)
As Announced
The emphasis is on planar microwave circuits and applications in microwave integrated circuits. Review of the theory of scattering matrix and signal flow graphs. Characteristics of the stripline, microstrip, coplanar waveguide, slot line and fin line. Circuit

discontinuities. Design of planar lumped elements: inductors, capacitors and resistors. Impedance matching and tuning including the operation of matching transformers. Microwave resonators including microstrip and dielectric resonators. Power dividers, directional couplers and hybrids. This will include the principle of operation of the Wilkinson power divider and the Lange coupler. Design of microwave filters using the image parameter method and insertion loss method. Filter transformations and implementation. Touchstone and Libra software is to be used in design problems. *Prep. ECE 3101 or equivalent.*

ECE 3797 Engineer Degree Thesis Continuation (0QH)
Candidates to register for thesis continuation if their thesis is not completed after they have registered for three consecutive quarters or ten quarter hours of EE degree thesis. Continuous registration is required until candidate graduates. * *Please note that the Engineer Degree program has been terminated as of the 1998/99 academic year. The Engineer Degree Thesis and Engineer Degree Thesis Continuation courses apply to those students already in the Engineer Degree program.*

ECE 3798 Master's Continuation (0QH)
Any Quarter

ECE 3799 PhD Thesis Continuation (0QH)
Any Quarter

ECE 3860 Master's Thesis (8QH)
Any Quarter
Analytical and/or experimental work conducted under the auspices of the department. *Prep. Bachelor of Science Degree in Engineering or Science.*

ECE 3861 Master's Thesis (4QH)
Any Quarter

ECE 3862 Master's Thesis (2QH)
Any Quarter

ECE 3863 Master of Science Project (4QH)
Any Quarter
Analytical and/or experimental work leading to a written report and a final exam consisting of a poster session together with a 5-minute presentation. The student is required to select an advisor, who will be responsible for the grade, and one other ECE faculty member. All M.S. Projects shall be presented at one poster session together with 5-minute presentations scheduled the Friday before final exam week. *Prep. Permission of the Graduate Committee.*

ECE 3870 Engineering Degree Thesis (8QH)
Any Quarter
Analytical and/or experimental work conducted under the auspices of the department. Minimum of 4QH, maximum of 8QH allowed per quarter. *Prep. Admission to Engineer Program.* * *Please note that the Engineer Degree program has been terminated as of the 1998/99 academic year. The Engineer Degree Thesis and Engineer Degree Thesis Continuation courses apply to those students already in the Engineer Degree program.*

ECE 3871 Engineer Degree Thesis (4QH)
Any Quarter
* *Please note that the Engineer Degree program has been terminated as of the 1998/99 academic year. The Engineer Degree Thesis and Engineer Degree Thesis Continuation courses apply to those students already in the Engineer Degree program.*

ECE3872 Engineer Degree Thesis (2QH)
Any Quarter
* *Please note that the Engineer Degree program has been terminated as of the 1998/99 academic year. The Engineer Degree Thesis and Engineer Degree Thesis Continuation courses apply to those students already in the Engineer Degree program.*

ECE 3880 Doctoral Thesis (0QH)
Theoretical and/or experimental work conducted under the auspices of the department. *Prep. Passing of PhD Qualifying Exam.*

ECE 3889 Doctoral Seminar (0QH)
Any Quarter
This requirement will be satisfied by the student presenting a seminar to the Electrical Engineering Department on a subject related to his/her PhD thesis. The thesis supervisor will coordinate the seminar. *Prep. Passing of PhD Qualifying Exam.*

ECE 3892 Doctoral Reading (0QH)
Any Quarter
Material approved by the candidate's advisor (only S or F Grades will be assigned for this course). *Prep. Passing of PhD Qualifying Exam.*

ECE 3896 Special Problems in Electrical Engineering (4QH)
Any Quarter
Theoretical or experimental work under individual faculty supervision.

Information Systems

The Graduate School of Engineering offers the degree of Master of Science in Information Systems, which relies heavily on courses from the Mechanical, Industrial and Manufacturing Engineering Department. The program is designed for students and professionals who desire to make a career shift to the information systems field or professionals currently in the field who wish to enhance their skills and credentials. The many disciplines from which students switch include: liberal arts, life sciences, physical sciences, computer science, mathematics, business, and engineering. The successful applicant must demonstrate an inherent affinity for analytical thinking.

Applicants are required to submit GRE results, unless explicitly waived. The program may be pursued on a part-time or full-time basis by persons currently employed in the information systems profession. All other applicants are generally expected to enroll as full-time students for three quarters, with the option of completing the program on a part-time or cooperative education basis. Seminars are provided to introduce students to the information systems industry and to develop job-search skills.

Please see the applicable department for course descriptions. Contact the host college for courses outside of the College of Engineering (i.e. Business, Computer Science, Arts and Sciences, etc.).

MASTER OF SCIENCE DEGREE REQUIREMENTS

A minimum of 44 quarter hours of credit and a minimum grade point average of 3.00 is required for the MSIS degree. A maximum of 12 quarter hours of graduate credit from outside the College of Engineering may be counted toward the degree, including courses from institutions other than Northeastern University. All transfer credit must be approved by petition before course enrollment.

It is expected that students beginning this program will have an adequate background in the following areas: C programming language, discrete structures, calculus, and probability and statistics. Deficiencies in this background may be remedied by taking the appropriate prerequisite courses listed below. A maximum of six quarter hours of graduate credit from the prerequisite courses can be applied to the degree as open elective courses. Comparable courses may be substituted for prerequisite courses but only courses from this group can be applied toward the degree.

Prerequisite Courses		Credits
MTH 3212	Elements of Math for Information Systems 2 (Discrete Structures)	2
MTH 3213	Elements of Math for Information Systems 3 (Data Analysis, Model Building and Calculus)	2

MTH 3214 Elements of Math for Information Systems 4 (Probability and Statistics) 2
MIM 3132 C/UNIX for Information Systems 4

Course Requirements

Core Courses ..... 24 QH
Technical Elective Courses ..... 12 QH
Open Elective Courses ..... 8 QH
Minimum Quarter Hours Required* ..... 44 QH

* includes a maximum of 6 QH of prerequisite courses

Core Courses-24 QH

MIM 3104 Data Structures 4
MIM 3107 Operating Systems and Systems Software 4
MIM 3110 Computer Architecture 4
MIM 3115 Introduction to Software Engineering and Computer Technology 4
MIM 3122 PC Architecture and Systems Programming 4
MIM 3128 Data Base Management Systems 4

Technical Elective Courses-Select 12 QH*

MIM 3102 Planning and Managing Information Systems Development 4
MIM 3124 Software Engineering 4
or ECE 3311 Software Engineering 4
MIM 3126 Networks and Telecommunications 4
MIM 3129 Expert Systems in Engineering 4
MIM 3130 Machine Intelligence 4
MIM 3131 Machine Learning 4
MIM 3133 C++ Object Oriented Design 4
MIM 3137 Programming Languages for Software Engineering 4
MIM 3140 JAVA with Engineering Applications 4
MIM 3141 Advanced JAVA Development 4
MIM 3217 Engineering Project Management 4
ECE 3469 Fault-Tolerant Computers 4
ECE 3480 Distributed Systems 4
ECE 3483 Multiprocessor Architecture 4
COM 3316 Transaction Processing Systems 4
COM 3317 Data Modeling 4
COM 3337 Distributed Operating Systems 4
COM 3375 Human/Computer Interaction 4
COM 3520 Cryptography and Computer Security 4
COM 3560 Distributed Database Systems 4
MSC 3950 Fundamentals of Information Systems** 3
MSC 3952 Information Policy** 3

* other courses may be used as Technical Electives with approval of the academic advisor
** a maximum of one of these courses may be counted as a Technical Elective

Open Elective Courses - Select 8 QH

Open electives may be selected from any graduate program within Northeastern or from graduate programs at other institutions, subject to approval by the academic advisor and the 12 QH credit transfer maximum. These electives may be used to complement the material of the technical elective courses or to enhance the depth or breadth of the program.

FACULTY ASSOCIATED WITH THE PROGRAM

Dr. David Kaeli, Electrical and Computer Engineering Department
Dr. Mieczyslaw Kokar, Electrical and Computer Engineering Department
Dr. Ronald Mourant, Mechanical, Industrial and Manufacturing Engineering Department
Dr. Ronald Perry, Mechanical, Industrial and Manufacturing Engineering Department
Jennifer Black, Mechanical, Industrial and Manufacturing Engineering Department

Program Coordinator and Academic Advisor

Prof. Ronald Perry, Mechanical, Industrial and Manufacturing Engineering Department

Department of Mechanical, Industrial and Manufacturing Engineering

The Department of Mechanical, Industrial and Manufacturing Engineering offers the following graduate degree programs:

Master of Science in Mechanical Engineering
Master of Science in Industrial Engineering
Master of Science in Engineering Management
Master of Science in Operations Research
(In conjunction with the Mathematics Department)
Doctor of Philosophy in Mechanical Engineering
Doctor of Philosophy in Industrial Engineering

The department also hosts the following Graduate School of Engineering programs:

Master of Science in Computer Systems Engineering - CAD/CAM Option
Master of Science in Computer Systems Engineering - Engineering Software Design Option
Master of Science in Information Systems

Details for the Master of Science in Computer Systems Engineering and the Master of Science in Information Systems degrees can be found elsewhere in this catalogue. Students accepted into the other Master's programs listed above must have a Bachelor of Science degree in engineering, science, mathematics, or equivalent. All programs may be taken either on a full-time or part-time basis, but restrictions may apply.

A maximum of 12 quarter hours of graduate course work from outside the Department of Mechanical, Industrial and Manufacturing Engineering may be counted toward any master's degree in the department. These courses may be taken either within Northeastern University or from other institutions. All such transfer credit must be approved by petition.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING
DEGREE REQUIREMENTS

A minimum of forty-four quarter hours of graduate study is required for this degree. Full-time students, both continuous and cooperative, are required to complete a seminar program and a thesis for twelve quarter hours of credit. The thesis and seminar program are not required of part-time students. All students must consult with their advisor or the Department's assigned Graduate Officer for course sequencing and the selection of elective courses in each area of concentration. The curriculum offers areas of concentration in Mechanics and Design, Thermofluids Engineering, and Materials Science and Engineering.

Mechanics and Design

Course Requirements	**Full-time Study**	**Part-time Study**
Required Core Courses	16 QH	16 QH
Required Electives	10 QH	18 QH
Thesis	12 QH	0 QH
Other Courses	6 QH	10 QH
Minimum Quarter Hours Required *	44 QH	44 QH

* exclusive of any preparatory courses

Required Core Courses

			Credits
MIM	3000	Mathematical Methods for Mechanical Engineers	4
MIM	3600	Theory of Elasticity	4
MIM	3630	Vibration Theory and Applications	4
MIM	xxxx	Required Core Course from Thermofluids Engineering or Materials Science and Engineering	4

Required Electives (10 or 18 QH from the following list)

MIM	3610 - MIM 3695		
MIM	3005	Advanced Mathematical Methods for Mechanical Engineers	4
MIM	3010	Numerical Methods in Mechanical Engineering	4
MIM	3300	Manufacturing Design and Computers	4
MIM	3325	Robot Mechanics and Control	4
MIM	3350	Computer Aided Graphics and Design	4

Advanced Electives in Mechanics or Design

Thesis (0 or 12 QH)

MIM	3925	Thesis (Master of Science Degree)	2
MIM	3930	Thesis (Master of Science Degree)	4
MIM	3935	Thesis (Master of Science Degree)	8

Other Courses (6 or 10 QH)

Advanced Courses in Engineering or Science with no more than six (6) quarter hours outside the department.

Thermofluids Engineering

Course Requirements	Full-time Study	Part-time Study
Required Core Courses	16 QH	16 QH
Required Electives	8 QH	8 QH
Thesis	12 QH	0 QH
Advanced MIM Electives	0 QH	12 QH
Other Courses	8 QH	8 QH
Minimum Quarter Hours Required *	44 QH	44 QH

* exclusive of any preparatory courses

Required Core Courses

			Credits
MIM	3000	Mathematical Methods for Mechanical Engineers	4
MIM	3700	General Thermodynamics	4
MIM	3750	Essentials of Fluid Dynamics	4
MIM	xxxx	Required Core Course from Mechanics or Materials Science and Engineering	4

Required Electives Selection

MIM	3710	Statistical Thermodynamics	4
MIM	3720	Heat Conduction and Thermal Radiation	4
MIM	3725	Convective Heat Transfer	4
MIM	3760	Viscous Flow	4
MIM	3765	Gas Dynamics	4
MIM	3792	Fundamentals of Combustion	4

Thesis (0 or 12)

MIM	3925	Thesis (Master of Science Degree)	2
MIM	3930	Thesis (Master of Science Degree)	4
MIM	3935	Thesis (Master of Science Degree)	8

Advanced MIM Electives (0 or 12)

MIM	3005	Advanced Mathematical Methods for Mechanical Engineers	4
MIM	3010	Numerical Methods in Mechanical Engineering	4
MIM	3300	Manufacturing Design and Computers	4
MIM	3325	Robot Mechanics and Control	4
MIM	3350	Computer Aided Graphics and Design	4

MIM 3710-MIM 3795, excluding MIM 3750, MIM 3800-3890

Other Courses (8 QH)

Advanced Courses in Engineering or Science with no more than eight (8) quarter hours outside the department 8

Materials Science and Engineering

Course Requirements	Full-time Study	Part-time Study
Required Core Courses	20 QH	20 QH
Math. Elective	4 QH	4 QH
Advanced Materials Electives	0 QH	12 QH
Advanced Courses in Engineering, Math. and Science	8 QH	8 QH
Thesis	12 QH	0 QH
Minimum Quarter Hours Required	44 QH	44 QH

Required Core Courses **Credits**

MIM	3800	Strengthening Mechanisms	4
MIM	3806	Phase Transformations	4
MIM	3820	Thermodynamics of Materials	4
MIM	3825	Electronic Behavior I	4
MIM	xxxx	Required Core Course from Mechanics or Thermofluids Engineering	4

* MIM 3000 and MIM 3700 not eligible

Math Electives

MIM	3000	Math. Methods for Mechanical Engineers	4
MIM	3423	Applied Statistics	4
or MTH	3222	Applied Statistics	4
MIM	3400	Basic Probability and Statistics	4

Thesis (0 or 12)

MIM	3925	Thesis (Master of Science Degree)	2
MIM	3930	Thesis (Master of Science Degree)	4
MIM	3935	Thesis (Master of Science Degree)	8

Advanced Materials Electives

MIM	3665	Engineering Fracture Mechanics	4
MIM	3670	Advanced Engineering Fracture Mechanics	2
MIM	3800 - MIM 3890		26
CHE	3600	Polymer Science	4
ECE	3384, 3388	Solid State Devices I, II	4 each
ECE	3583, 3584, 3585	Optical Properties of Matter	2 each
ECE	3600	Microwave Properties of Materials	4
ECE	3626, 3629	Integrated Circuit Fabrication Processes	4 each

Advanced Courses in Engineering, Math. and Science

These courses include those listed under Advanced Materials Electives as well as those in other departments in the university.

MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING
DEGREE REQUIREMENTS

This degree requires either an eight quarter hour thesis or a four quarter hour special project. Arrangements for and approval of the topic for the special project or thesis must be made with a member of the full-time faculty of the department. All MSIE students must take the core courses shown below. Equivalent substitutions must be approved by a petition.

Course Requirements	**With Thesis**	**With Project**
Core Courses	24 QH	24 QH
Electives	8 QH	12 QH
Thesis or Project	8 QH	4 QH
Minimum Quarter Hours Required	40 QH	40 QH

Required Core Courses			**Credits**
MIM	3215	Engineering Economy	4
MIM	3400	Basic Probability and Statistics	4
MIM	3423	Applied Statistics	4
MIM	3503	Simulation Methodology and Applications	4
MIM	3530	Operations Research I	4
MIM	3320	Production Analysis	4

The remaining course work is satisfied by elective courses. A student may opt for a concentration in Computers and Information Systems, Manufacturing Systems, Operations Research, or Quality Control and Reliability Analysis by taking the required courses for the elective concentration listed below.

Courses for Elective Concentrations*

Computers and Information Systems			**Credits**
MIM	3104	Data Structures	4
MIM	3115	Analysis and Design of Computer Information Systems	4
MIM	3128	Data Base Management Systems	4

Manufacturing Systems (Any three of the following courses)*

MIM	3305	Manufacturing Methods and Processes	4
MIM	3310	Computer Methods in Manufacturing	4
MIM	3315	Neural Networks in Manufacturing	4
MIM	3375	Computer-Aided Manufacturing	4

Operations Research (Any three of the following courses)*

MIM	3503	Simulation Methodology and Applications	4
MIM	3524	Multi-Criteria Decision Making	4
MIM	3531	Operations Research II	4
MIM	3532	Operations Research III	4

Quality Control and Reliability Analysis

MIM	3416	Statistical Quality Control	4
MIM	3425	Intro. to Reliability Analysis and Risk Assessment	4
MIM	3435	Reliability Engineering and Testing	4

* Concentration electives are 12 quarter hours.

MASTER OF SCIENCE IN ENGINEERING MANAGEMENT DEGREE REQUIREMENTS

The core course requirements for the Engineering Management program are listed below:

Core Courses	24 QH
Electives	16 QH
Minimum Quarter Hours Required	40 QH

Required Core Courses **Credits**

MIM	3207	Financial Management	4
MIM	3215	Engineering Economy	4
MIM	3217	Engineering Project Management	4
MIM	3400	Basic Probability and Statistics	4
MIM	3423	Applied Statistics	4
MIM	3530	Operations Research I	4

The remaining course work is satisfied by elective courses. A student may select 16 quarter hours of elective courses or opt for a concentration in Computers and Information Systems, Manufacturing Systems, Operations Research, or Quality Control and Reliability Analysis by taking the required courses for the elective concentration listed above.

MASTER OF SCIENCE IN OPERATIONS RESEARCH DEGREE REQUIREMENTS

The MSOR degree is offered jointly by the Department of Mechanical, Industrial and Manufacturing Engineering and the Mathematics Department. The program builds on the student's background in mathematics or engineering to provide the skills needed to solve problems involving optimization, probability, and statistics. An applicant may apply for admission to the program through either the Department of Mechanical, Industrial and Manufacturing Engineering or the Mathematics Department. Students will receive their degree from the college in which they are enrolled. The required and elective courses for the degree are specified below.

Core Courses	24 QH
Electives *	16 QH
Minimum Quarter Hours Required	40 QH

* A thesis (8 QH) is optional in place of 8 QH of electives.

Required Core Courses			Credits
MIM	3400	Basic Probability and Statistics	4
or MTH	3431	Probability 1	4
MIM	3523	Applied Statistics	4
or MTH	3441	Statistics 1	4
MIM	3530	Operations Research I	4
MIM	3531	Operations Research II	4
MTH	3373	Optimization	4
MTH	3432	Probability I	4

The remaining course work is satisfied by 16 QH of elective courses. The following courses may be taken as electives:

MSOR Elective Courses*			Credits
MIM	3104	Data Structures	4
or MTH	3501	Data Structures	4
MIM	3320	Production Analysis	4
MIM	3409	Design of Experiments	4
MIM	3425	Introduction to Reliability Analysis and Risk Assessment	4
MIM	3435	Reliability Engineering and Testing	4
MIM	3503	Simulation Methodology and Applications	4
MIM	3510	Forecasting	4
MIM	3512	Inventory Theory	4
MIM	3513	Network Analysis and Advanced Linear Programming	4
MIM	3515	Queuing Theory	4
MIM	3524	Multi-Criteria Decision Making	4
MIM	3532	Operations Research III	4
MTH	3443	Statistical Decision Theory	4
MTH	3452	Time Series	4
MTH	3524	Discrete Mathematical Models	4
MTH	3527	Combinatorics 1: Enumeration	4
MTH	3529	Graph Theory	4
COM	3390	Analysis of Algorithms	4
MTH	3535	Complexity Theory	4
or COM	3730	Complexity Theory	4

* Other courses may be selected with approval of an academic advisor.

THE DOCTOR OF PHILOSOPHY DEGREE

The degree of Doctor of Philosophy (Ph.D.) is awarded to those candidates who demonstrate high attainment and research competence in the field of Mechanical Engineering or Industrial Engineering. Upon acceptance into the program, a student is designated a Doctoral Student. A doctoral student who has completed the equivalent of an MS program in Mechanical or Industrial Engineering or 40 quarter hours of graduate work with satisfactory grades becomes a Doctoral Candidate upon successful completion of the Doctoral Qualifying Examination. After candidacy has been established,

a candidate must complete a dissertation under the direction of a Dissertation Advisor and a program of course work. To receive the Ph.D. degree a candidate must pass a Final Oral Examination.

Qualifying Examination

The Qualifying Examination is offered twice yearly, on the third Friday of November and May, and comprises both written and oral parts. The objective of the written part is to test the student's knowledge and comprehension of the basic concepts and fundamentals in mechanical engineering and/or industrial and computer systems engineering. The oral part is administered to test general comprehension and capability for successful completion of the program. All Doctoral Students must take the qualifying examination within 12 months of acceptance into the program. Because degree candidacy must be established before the Graduate Committee will act to approve the course program and dissertation proposal, the qualifying examination should be taken at the earliest opportunity.

The written part is six hours in length and covers, with equal emphasis, four different areas from among the nine groups listed below. At least two of the four areas must be directly related to the student's research concentration. To provide breadth, at least one of the four areas must lie outside both the research concentration and Group A. The selection of all areas must be made in consultation with the Dissertation Advisor. All examinations shall be closed book and notes. Students may prepare and use a single double-sided 8½×11 sheet of reference materials for each examination. There shall be no student access to sample examinations. Students seeking guidance beyond that presented in The PhD Qualifying Examination Manual as prepared and distributed by the Graduate Committee may speak with their advisors.

The oral part is conducted by a committee consisting of at least four members appointed by the Graduate Committee. A typical committee is composed of at least one member from each of the four specialty areas in which the student has chosen to be examined in the written part and includes the Dissertation Advisor.

Students will have a maximum of two attempts to achieve candidacy to the PhD program. Those not admitted to candidacy after the second attempt will no longer be eligible for candidacy in any of the department's PhD programs.

A student who is classified as interdisciplinary may request modifications in testing areas. The request must be approved by the Graduate Committee.

List of Groups and Areas:

A. Engineering Mathematics, Engineering Computation, Probability and Statistics
B. Thermodynamics, Fluid Mechanics, Heat Transfer
C. Dynamics and Vibrations, Mechanics of Deformable Bodies, Dynamic Systems and Control
D. Materials Science, Mechanical Behavior of Materials, Physical Metallurgy
E. Design and CAD/CAM
F. Human-Machine Systems
G. Manufacturing Systems, Production and Logistics
H. Operations Research, Reliability and Quality Assurance, Simulation
I. Software Engineering, Programming Languages, Artificial Intelligence in Engineering

Dissertation and Course Requirements

Within two academic quarters after degree candidacy has been established, the doctoral candidate has to petition the graduate committee to appoint a Dissertation Committee. The Dissertation Committee will be chaired by the student's dissertation advisor and must include at least two other members, with one member from outside the student's major area. The doctoral candidate will propose a Dissertation Topic and Program of Study to the Dissertation Committee for its approval within one year after degree candidacy has been established. A typical program includes at least 36 quarter hours of course work beyond the M.S. degree with at least 12 quarter hours of the course work in a discipline other than that in which the candidate is concentrating (which may also be taken outside the department). Attainment of a minimum 3.00 grade point average for the courses in the "minor" portion of the program will signify satisfactory completion of that portion of the course work. Upon successful completion of the PhD qualifying examination and the majority of required course work, the student is required to register in three consecutive quarters for MIM 3985 (Dissertation). Upon completion of this sequence, the student is required to register for MIM 3990 (PhD Continuation) in every quarter until the dissertation has been completed. Students may not register for continuation until the three-quarter thesis sequence has been fulfilled.

Final Oral Examination

A Final Oral Examination is scheduled after the Dissertation Committee agrees that the dissertation is in an appropriate form for a formal presentation and after completion of all other requirements for the Ph.D. degree. Upon successful completion of the examination, the doctoral candidate is recommended to receive the Ph.D. degree.

Residence Requirement

The residence requirement is satisfied by one year of full-time graduate work or by two years of half-time graduate work beyond the Master of Science degree. However, a student should expect to spend at least three years, or the equivalent, in full-time graduate study beyond the requirements of the Master of Science degree.

FACULTY

John W. Cipolla Jr., Chairman
Mohamad Metghalchi, Associate Chairman

Professors

Adams, George G., PhD, University of California at Berkeley; vibrations, elasticity, tribology, moving loads on structures, applications to information storage and processing systems

Cipolla, John W., Jr., Donald W. Smith Professor of Mechanical Engineering, PhD, Brown University; laser-aerosol interactions including thermophoresis, heat and mass transfer, radiative transfer, kinetic theory

Cullinane, Thomas P., PhD, Virginia Polytechnic and State University; manufacturing systems, facilities planning, project management

Gorlov, Alexander M., PhD, Moscow Institute of Transport Engineers; mechanical design of complex systems, mechanical apparatus for harnessing tidal and low head hydro power, transporting of ships by land, general applied mechanics problems

Hashemi, Hamid N., PhD, Massachusetts Institute of Technology; materials, composite materials, nondestructive evaluation, mechanics, finite-elements, fatigue, wear, reliability-centered maintenance

Mourant, Ronald R., PhD, Ohio State University; human factors, ergonomics, human-computer interfaces, virtual environments, simulators for manufacturing operations and driving

Murphy, Richard J., PhD, Massachusetts Institute of Technology; metal matrix composites

Nowak, Welville B., Senior Research Scientist and Professor (Emeritus), PhD, Massachusetts Institute of Technology; materials science and engineering, thin films for resistance to corrosion, diffusion and wear, photovoltaic solar cells, electronic materials

Rossettos, John N., PhD, Harvard University; buckling and vibration of stiffened plates, mechanics of damage in composite materials, applied mechanics

Soyster, Allen L., PhD, Carnegie-Mellon; total quality management in acquisition process, applications of expert systems and artificial intelligence to building production scheduling systems, mathematical optimization of data analysis, modeling of energy distribution and transfer process

Taslim, Mohammad E., PhD, University of Arizona; computational and experimental fluid mechanics and heat transfer with applications in gas turbines, film cooling

Yener, Yaman, PhD, North Carolina State University; heat and mass transfer, radiative transfer, aerosolthermophoresis with radiation, thermal stability, spectral methods

Zeid, Ibrahim, PhD, University of Akron; CAD/CAM, design, manufacturing, case-based reasoning, Java and Web-based engineering applications

Associate Professors

Ando, Teiichi, Ph.D, Colorado School of Mines; physical metallurgy, rapid solidification, processing, powder metallurgy, spray forming, droplet-based materials processing and manufacturing, microstructural evolution in materials processing

Blucher, Joseph T., PhD, Massachusetts Institute of Technology; surface treating processes CVD, PVD, ion nitriding, and laser processing, metal matrix composites, powder metallurgy, welding, cutting tools, manufacturing processes, failure analysis, fracture, fatigue, wear

Fard, Nasser, PhD, University of Arizona; reliability analysis, quality engineering, stochastic modeling

Gupta, Surendra M., PhD, Purdue University; simulation, operations research, production systems, stochastic modeling, environmentally conscious manufacturing

Ilegbusi, Olusegun J., PhD, Imperial College of Science and Technology, University of London; turbulence modeling, multiphase flow, mathematical modeling of materials processing operations, thermodynamics, non-Newtonian flow, bio-fluids mechanics

Kowalski, Gregory J., PhD, University of Wisconsin-Madison; combined modes of heat transfer in participating media, solar energy, thermal electronic packaging, combined heat and mass transfer

Levendis, Yiannis A., PhD, California Institute of Technology; combustion, incineration, air pollution, chemical kinetics, aerosol physics, internal combustion engines

Melachrinoudis, Emanuel S., PhD, University of Massachusetts; operations research, stochastic modeling, facilities planning, manufacturing systems

Messac, Achille, PhD, Massachusetts Institute of Technology; structures, structural dynamics, multibody dynamics, control, multidisciplinary design optimization, optimization, mechanics, analytical and computational CAD, finite element analysis, physical programming

Metghalchi, Mohamad, ScD, Massachusetts Institute of Technology; laminar and turbulent flame propagation, stability in internal combustion engines, energy conversion, air pollution, chemical kinetics, advanced thermodynamics

Narusawa, Uichiro, PhD, University of Michigan; natural and double-diffusive convection in enclosures and saturated porous media, two-phase flows, thermocapillary flow

Perry, Ronald F., PhD, University of Michigan; simulation, management information systems

Voland, Gerald, PhD, Tufts University; engineering design, engineering systems, cross-disciplinary education

Assistant Professors

Benneyan, James C., Ph.D, University of Massachusetts; quality engineering, statistical quality control, inspection error models, computer simulation, industrial experiments, application in manufacturing and healthcare, including semiconductor fabrication and cancer screening

Isaacs, Jacqueline, PhD, Massachusetts Institute of Technology; processing and properties of metal matrix composites, environmental and life cycle issues in advanced and emerging technologies, manufacturing economics of materials processing in automotive industry

Kamarthi, Sagar, PhD, Pennsylvania State University; neural networks and knowledge-based systems in design and manufacturing, process monitoring and control, sensor integration, and product realization in mass customization

Wilson, Bruce H., PhD, University of Michigan; mechanical computer-aided engineering, automated modeling, dynamic systems and control, computer-aided design and control of drive train systems, robust control, uncertain modeling

Associated Faculty

Cole, William E., PhD, Pennsylvania State University; energy use, combustion, pollutant emissions, industrial manufacturing processes, computer modeling of industrial manufacturing processes, applications of neural networks

PROGRAM ADVISORS

Mechanical Engineering	
Mechanics and Design Concentration	Prof. H.N. Hashemi
Thermofluids Engineering Concentration	Prof. M. Taslim
Materials Science and Engineering Concentration	Prof. R. J. Murphy
Industrial Engineering	Prof. S. Gupta
Engineering Management	Prof. T. Cullinane
Operations Research	Prof. E. Melachrinoudis
Information Systems	Prof. R. Perry
Computer Systems Engineering (CAD/CAM)	Prof. I. Zeid
Computer Systems Engineering (Engineering Software Design)	Prof. R. Mourant

*Each course description includes information on the expected quarter in which classes are usually offered. The quarters listed are presented here for planning purposes; however, the Graduate School of Engineering cannot guarantee that all courses will be offered. Students must refer to the Graduate School of Engineering Quarterly Course Offering sheets to determine what courses are actually offered in any given quarter and at what day and time. "Odd" and "Even" years refer to the fall quarter of the academic year, e.g., Spring 98 which is in the 98/99 academic year, would be an "even" year. Burlington campus offerings are designated with a *.*

MIM 3000 Mathematical Methods for Mechanical Engineers (4QH)
Fall Quarter
(formerly ME 3100)
A comprehensive course designed to integrate undergraduate mathematics into a solid foundation of graduate mathematics. Topics will likely include infinite series, generalized functions and the Laplace transform, special functions, vector field theory, linear space theory, and eigenvalue and eigenfunction theory. These techniques and other methods will be used to solve both ordinary and partial differential equations. *Prep. Admission to the Graduate School of Engineering.*

MIM 3005 Advanced Mathematical Methods for Mechanical Engineers (4QH)
Fall Quarter, Odd Years
(formerly ME 3400)
Variational calculus and applications. Complex variables. Approximate methods of engineering analysis. Integral transforms; asymptotic expansion; regular and singular perturbation methods. Examples drawn from solid mechanics, vibration, and fluid mechanics. *Prep. MIM 3000.*

MIM 3010 Numerical Methods in Mechanical Engineering (4QH)
Winter Quarter
(formerly ME 3410)
Numerical methods applied to problems in mechanical engineering. Solution of linear and non-linear systems of equations, interpolation and regression, numerical differentiation and integration, numerical solution of ordinary differential equations: explicit and implicit methods, multi-step methods, predictor-corrector methods. Numerical solution of partial differential equations with emphasis on parabolic and elliptic problems occurring in mechanical engineering. *Prep. MIM 3000 and good knowledge of a programming language.*

MIM 3025 Human Factors Engineering (4QH)
Fall Quarter
(formerly IIS3400)
Sensory motor and work environment considerations. Topics include the design of equipment and systems for human use, with the application of engineering psychology; visual and auditory presentation of information; human information processing and skilled task performance. The human as a work-performing, heat generating physiological engine, and the implied restrictions on the equipment and work place to provide occupational safety and effective man/machine performance. *Prep. Admission to Graduate School.*

MIM 3030 Human-Computer Interaction (4QH)
As Announced
(formerly IIS 3405)
This course considers the design of the computer-user interface. Emphasis is given to the needs and capabilities of the user, as well as to the computer-user interface designer's viewpoint. Ergonomic principles of design, particularly those pertaining to design of displays and controls, form a major component of the course. *Prep. Admission to the Graduate Program.*

MIM 3102 Planning and Managing Information Systems Development (4QH)
Winter and Spring* Quarter
(formerly IIS 3218)
Provides an overview of the most popular Information Systems (IS) needs assessment methodologies including: Portfolio Analysis, Stage Assessment, Business Systems Planning and Alloway Survey Technique. Utilizes IS strategic plan components of business goal alignment, architecture planning, cost/benefit & risk analysis, and plan phasing techniques to demonstrate how businesses match needs to budgetary constraints. Options for the placement of the IS management function within the organization, methods to manage the function, and the use of business system planning tools to reengineer business processes are discussed and evaluated. Cases studies

of actual business situations are utilized extensively. *Prep. MIM 3115*

MIM 3103 Introduction to Formal Methods in Software Engineering (4QH)
As Announced
This course introduces mathematics and methods necessary for 1) formal specification of software requirements, 2) formal verification of software, 3) development of software through progressive refinement of specifications. Topics include: propositional and predicate calculus, formal systems, theories of sets, relations, functions, sequences and algebras, model and theory based specification methods and examples, formal method tools, elements of theory of algorithm complexity. *Prep. MIM 3124.*

MIM 3104 Data Structures (4QH)
Fall, Winter and Spring* Quarters
(formerly IIS 3604)
An introduction to basic concepts of data structures. Topics include arrays, stacks, lists, linked lists, queues, trees, graphs, symbol and hash tables, and files. An abstract data type for each data structure is presented and various implementations in a high level language are discussed. Algorithms for handling data are analyzed. Applications of particular structures are shown in order to emphasize abstraction in problem solving with computers. Searching and sorting techniques are also covered. *Prep. MIM 3132 or equivalent.*

MIM 3107 Operating Systems and Systems Software (4QH)
Fall, Winter* and Spring Quarters
(formerly IIS 3607)
An exploration of the underlying algorithms and policies which influence the development and execution of modern operating systems. Consideration will be given to operating systems facilities which assist the design and implementation of application programs. The topics include process concurrency, synchronization, deadlock, multiprogramming, virtual memory, process scheduling, security, and protection. The UNIX operating system will be used as a model with several programming assignments using UNIX system calls. *Prep. MIM 3104 and MIM 3110.*

MIM 3110 Computer Architecture (4QH)
Fall*, Winter and Spring Quarters
(formerly IIS 3610)
Fundamental concepts in computer architecture and organization are investigated. Topics include the history and evolution of computers; digital logic, gating, timing diagrams, and control signals; interconnection structures such as buses and data paths; data storage devices, interfaces, and organization; I/O devices and technology; interrupts and DMA; and cache and paging. An emphasis is placed upon CPU architecture, including binary arithmetic and organization of the ALU, instruction types, formats, addressing modes, and pipelining. Microprogramming of the CPU's control unit is considered in detail, and RISC architectures are surveyed. *Prep. MIM 3122 (for Information Systems students only).*

MIM 3115 Introduction to Software Engineering and Computer Technology (4QH)
Fall and Winter* Quarters
(formerly IIS 3615)
Introduction to software engineering analysis and design techniques and computer technology. Topics covered include: techniques for determining information requirements for MIS/DSSs; development of the functional systems design; and computer system design considerations such as the CPU, main memory, operating systems functions, computer languages, input devices, secondary memory, file organization, database management systems, data communications, data security, and output and display devices. The main objective of the course is to develop capability in the skeletal design of a computer system to support a given set of information requirements. *Prep. Admission to Graduate Program.*

MIM 3122 PC Architecture and System Programming (4QH)
Winter and Spring* Quarters
(formerly IIS 3622)
Presents fundamentals of the 80x86 family architecture and system programming. Topics covered include: evolution of 80X86 architecture through the Pentium Pro, memory organization, assembly language coding, file handling, video display, keyboard operations, BIOS and DOS interrupts, and DOS/Windows command structure. The focus of the course is the popular interrupt-driven operating system DOS/Windows and its underlying system programming concepts. Concrete understanding of concepts are enhanced through laboratory exercises. *Prep. MIM 3115.*

MIM 3124 (ECE 3311) Software Engineering (4QH)
Fall and Spring Quarters
(formerly IIS 3624)
A study of the software life cycle (requirements analysis and specification, software design, coding, testing, and maintenance). Verification, validation and documentation at various stages of the life cycle.

Coverage of structured analysis and object-oriented design methodologies. Overviews of user interface design, prototyping, CASE tools, software metrics, and software development environments. Emphasis on modular software construction and development of modular libraries. Course requirements include a small software development project. *Prep. MIM 3107.*

MIM 3125 Software Development and Evolution (4QH)
As Announced
(formerly IIS 3625)
The goal of this course is to introduce the students to the computer-aided software engineering (CASE) tools that aid in all the stages of software development. Topics include tools for documenting, requirements analysis and specification, validation and verification, software design and development, software generation, testing, and maintenance. *Prep. MIM 3124.*

MIM 3126 Networks and Telecommunications (4QH)
Winter Quarter
(formerly IIS 3626)
Network goals and applications; architecture, topologies, and protocols; layered communications protocol design; layer functions, interlayer interfaces, and peer processes; performance measures; data communication techniques; wide area and local networks; channel interfaces and access schemes; workstations and server nodes; distributed systems; internetworking. *Prep. MIM 3110.*

MIM 3128 Data Base Management Systems (4QH)
Fall* and Spring Quarters
(formerly IIS 3628)
Fundamental concepts and design of data base management systems (DBMS). Topics include the role of DBMS in organizations; alternative data base models - hierarchical, network and relational; underlying data structures for each data base model; example DBMS for each model type; design of an information system using a DBMS approach; practical experience with at least one DBMS on a microcomputer or minicomputer, such as RBase 5000 or Data-Trieve. *Prep. MIM 3104.*

MIM 3129 Expert Systems in Engineering (4QH)
Spring Quarter
(formerly IIS 3629)
An introduction to the theory, topics and applications of expert systems in engineering. Topics include knowledge representation (semantic networks, frames, production rules, logic systems), problem solving methods (heuristic search algorithms, forward and backward chaining, constraint handling, truth maintenance), approximate reasoning methods (Bayesian, Dempster-Shafer, fuzzy logic, certainty factors), expert system project management and knowledge engineering, expert system shells. Development of an expert system for engineering using an expert system shell is part of the course requirements. *Prep. Admission to Graduate Program.*

MIM 3130 Machine Intelligence (4QH)
Fall Quarter
(formerly IIS 3630)
This course deals with the area of intelligent computer systems, i.e., such that exhibit some behavior normally attributed to humans - solving problems, reasoning, learning, handling collections of expert knowledge. This course focuses on methods, techniques and implementations of computer systems for problem solving in the area of engineering. Topics include an overview of the field of artificial intelligence (AI), one of the AI programming languages (LISP or Prolog), knowledge representation formalisms and their implementations, search strategies and algorithms, planning, logic and theorem proving, constraint handling and truth maintenance systems, reasoning with uncertainty and heuristics, qualitative reasoning, and applications of artificial intelligence in engineering. *Prep. MIM 3104.*

MIM 3131 Machine Learning (4QH)
Winter Quarter
(formerly IIS 3631)
This course introduces the students to the problem of developing programs that can learn (i.e., increment their knowledge in the process of execution). It covers some basic principles, techniques, tools and algorithms for building learning systems. The course concentrates on the methods of implementation of the learning algorithms in software rather than on the human learning mechanisms. Classification of machine learning methodology, algorithms and programs is discussed. Current research being conducted in the field of machine learning at various institutions throughout the world is presented. *Prep. MIM 3130.*

MIM 3132 C/UNIX for Information Systems (4QH)
Fall, Winter and Spring Quarters
(formerly IIS 3632)
An introductory programming course using the C programming language and the UNIX operating system. Emphasis on structured programming

techniques. Topics covered include algorithms and modular design of code; data types, control structures, submodules, structures and arrays, recursion, input/output processing, pointers, abstract data types, UNIX system interface and shell programming. Note: This course is designed for students with no programming language experience. *Prep. Admission to Graduate Program.*

MIM 3133 C++ Object Oriented Design (4QH)
Winter Quarter
(formerly IIS 3633)
An introduction to the basic concepts of C++ and object-oriented design for engineering software design and information systems. Topics include data abstraction, constructors and destructors, inheritance, the C++ I/O library, overloaded operators, virtual functions and polymorphism, and the reference data type. Applications of C++ programming are shown in order to emphasize the use of classes in problem solving with computers. *Prep. MIM 3104.*

MIM 3137 Programming Languages for Software Engineering (4QH)
Spring Quarter
(formerly IIS 3637)
An introduction to programming languages is presented through a consideration of available procedural languages and of the principles of their design and implementation. Languages are surveyed historically, and insight is provided into aspects of programming languages such as control structures, parameter passing conventions, run-time structures, and binding time. Exposure to modern representative languages is given, including limited hands-on experience with block-structure languages, object-oriented languages, and languages for list processing and logic programming. *Prep. MIM 3104.*

MIM 3140 Java with Engineering Applications (4QH)
Fall and Summer Quarters
Introduction to object-oriented design and programming via the Java programming language; the use of inheritance and composition in software design; development of Java applets and applications; study of the Java class libraries including the abstract windowing toolkit for building human computer interfaces, the network package for development of client-server systems. A course project is required. *Prep. Knowledge of C programming.*

MIM 3141 Advanced Java Development (4QH)
As Announced
Coverage of advanced topics in Java such as: accessing databases with Java Database Connectivity (JDBC), the JDBC security model, the Remote Method Invocation (RPI) package, use of the Common Object Request Broker Architecture (CORBRA) with Java, the Java Native Methods Interface (JNI) and Java's Component Technology: Java Beans. *Prep. MIM 3140.*

MIM 3142 Building Virtual Environments (4QH)
As Announced
An object-oriented approach to building three-dimensional virtual worlds. The Java 3D API will be used to construct a scene graph, and to control viewing and rendering. The scene graph, a treelike structure which includes geometric data, attribute information, and the information needed to render the scene from a particular point of view will be studied. A student project to program behaviors in a virtual environment will be required. *Prep. MIM 3140 and/or MIM 3141.*

MIM 3152 Software Engineering Project I (4QH)
Spring Quarter
(formerly IIS 3652)
Team work under faculty supervision on a large software project. The projects are drawn from an engineering field, design, systems engineering, manufacturing, planning maintenance, reliability, quality control, risk assessment, project control, evaluation of alternatives, etc. The project may cover either the whole software development life cycle or a significant part of it. *Prep. MIM 3124.*

MIM 3153 Software Engineering Project II (4QH)
Summer Quarter
(formerly IIS3653)
Continuation of MIM 3152. *Prep. MIM 3152.*

MIM 3204 Engineering/Organizational Psychology (4QH)
Fall and Spring* Quarters
(formerly IIS3204)
An analysis of the purpose and functioning of organizations as the basic networks for achieving goals through coordination of effort, communication, and responsibility. The role and function of engineering organizations based on modern behavioral science concepts. The application of psychology to industry relative to human relations, group dynamics, tests and

measurements, personnel practices, training, and motivation. *Prep. Admission to Graduate Program.*

MIM 3207 Financial Management for Engineers (4QH)
Winter and Spring* Quarters
(formerly IIS 3207)
Study of the issues and processes of short-term financing on industrial firms; financial analysis of cases, supplemented by readings to develop familiarity with sources and uses of working capital as well as the goals and problems involved in its management. Also covered is the analysis necessary for such long-term financial decisions as issuance of stock or bonds; contracting of leases or loans, and financing of a new enterprise; mergers, capital budgeting, the cost of capital, and the valuation of a business. *Prep. Admission to Graduate Program*

MIM 3215 Engineering Economy (4QH)
Winter Quarter
(formerly IIS 3215)
Economic modeling and analysis techniques for selecting alternatives from potential solution to an engineering problem are explored. Measures of merit such as present worth, annual worth, rate of return, and benefit/cost techniques are considered. Recent techniques of economic analysis especially the tools of decision making will be examined. Decisions under uncertainty are explored. *Prep. MIM 3400.*

MIM 3217 Engineering Project Management (4QH)
Fall and Winter* Quarters
(formerly IIS 3217)
The optimization of schedules utilizing pertinent software tools such as the linear programming and project management packages will be undertaken. Other graphics software used to draw project diagrams such as Gantt charts, PERT diagrams, manpower loading charts and funding charts will be included. Determination of the critical path and comparison of actual performance with the planned schedule will be covered. The systems life cycle will be considered. Needs analysis, requirements definition, preliminary design, detailed design and implementation will be addressed in the context of project management. *Prep. Admission to Graduate Program.*

MIM 3300 Manufacturing, Design and Computers (4QH)
Spring Quarter
(formerly ME 3510)
Focuses on manufacturing and its relationship to design and computers. Covers fundamentals of manufacturing methods and systems. Examines relationship between design and various aspects of manufacturing. Computer modeling and related aids of various manufacturing activities are discussed. Topics include manufacturing systems, manufacturing processes, mechanical tolerancing, manufacturing features, process planning, principles of part programming (NC, CNC, DNC), and integration between CAD and CAM databases. Includes discussions of CAM packages. Students may gain hands-on experience by using in-house CAD and CAM facilities. *Prep. Admission to Graduate Program.*

MIM 3305 Manufacturing Methods and Processes (4QH)
Fall Quarter
(formerly IIS 3310)
The structures of polymers (thermoplastic, thermosetting and glasses). Manufacturing processes for polymers including thermoforming are included. Structure of metals, the manufacturing processes for metal forming are presented. Alloys and welding and brazing are also included. *Prep. Bachelor of Science Degree in Engineering or Science.*

MIM 3310 Computer Methods in Manufacturing (4QH)
Spring Quarter
(formerly IIS 3309)
In depth coverage of the use of computers in the system design and implementation of Computer Integrated Manufacturing (CIM) is presented. Possible topic areas are the ICAM definition language for modeling process, MRP, project management, manufacturing simulation and facility layout, CAD/CAM, database interface, and other important application of computers to manufacturing systems. *Prep. MIM 3375, MIM 3503, or permission of instructor.*

MIM 3315 Neural Networks in Manufacturing (4QH)
Winter Quarter
(formerly IIS 3308)
This course covers applications of neural networks to problems in manufacturing. The course will review background material on important neural network architectures such as feedforward neural networks, Kohonen's feature maps, radial basis function networks, and adaptive resonance theory networks. The major emphasis of the course will be neural network applications in several areas such as: group technology part family formation, conceptual design, manufacturing systems design, process optimization, process and machine tool monitoring and diagnosis,

system identification and control, and product inspection.

MIM 3320 Production Analysis (4QH)
Spring Quarter
(formerly IIS 3304)
Modern quantitative techniques of production planning and control considering deterministic and probabilistic models are presented. Topics include project planning, forecasting, aggregate planning and master scheduling, inventory analysis and control, materials requirement planning, job shop scheduling and dispatching problems. *Prep. MIM 3400 and MIM 3530.*

MIM 3325 Robot Mechanics and Control (4QH)
Fall Quarter
(formerly ME 3468)
Kinematics and dynamics of robot manipulators are the focus of the first part of the course. Kinematics cover the development of kinematic equations of manipulators, the inverse kinematic problems, and motion trajectories. Dynamics of manipulators for the purpose of control are covered employing Lagrangian mechanics. The second part of the course focuses on the control and programming of robot manipulators. Steady state errors and calculations of servo parameters are covered. High level programming languages are discussed. *Prep. Admission to the Graduate School of Engineering.*

MIM 3350 Computer Aided Graphics and Design (4QH)
Winter Quarter
(formerly ME 3500)
Basic aspects of interactive computer graphics are covered. Topics include hardware and software concepts, design principles for the user-computer interface, geometrical transformation, display architecture, and data structures. Algorithms for removing hidden edges and surfaces, shading models, and intensity and colors are also covered. The second part of the course deals with the concepts of computational and numerical geometry and design of curves and surfaces. Solid modeling techniques are presented. Discussions of in-house computer aided graphics and Design packages are included. *Prep. Admission to the Graduate School of Engineering.*

MIM 3375 Computer-Aided Manufacturing (4QH)
Winter Quarter
(formerly IIS 3311)
A first course (overview) of computer aided manufacturing. Covers the areas that encompass the term CAM, i.e., group technology, material requirements planning, part coding and classification, numerical control, part programming and management systems. Broad coverage of each of the areas is given to allow the student to gain an appreciation of the coming review of the automated factory. *Prep. Higher level language.*

MIM 3400 Basic Probability and Statistics (4QH)
Fall and Winter* Quarters
(formerly IIS 3113)
Fundamental concepts of probability. Events, sample space, discrete and continuous random variables. Density functions, mass functions, cumulative probability distributions and moment generating functions. Expectation of random variables. Common discrete and continuous probability distributions including binomial, Poisson, geometric, uniform, exponential and normal. Multivariate probability distributions, covariance and independence of random variables. Sampling and descriptive statistics. Parameter estimation, confidence intervals and hypothesis testing. *Prep. Admission to Graduate Program.*

MIM 3409 Design of Experiments (4QH)
Spring Quarter
(formerly IIS 3509)
Theory and application of experimental design techniques such as modeling and statistics which can optimize resources and improve decision making risks. This course will cover experiments with single and multiple factors of interest and consider experiments with high order experimental restrictions. Some additional analysis techniques will also be covered. *Prep. MIM 3423.*

MIM 3416 Statistical Quality Control (4QH)
Spring Quarter
(formerly IIS 3516)
This course is designed to study the fundamental concepts of quality planning, and improvements. Analysis and application of modern statistical process control methods, inspection error, and design of sampling plans will be given. Topics also include: software quality assurance, and study of the concepts of Deming, Ishikawa, Feigenbum, and Taguchi's approach in quality planning, organization, and improvement. *Prep. MIM 3400.*

MIM 3423 Applied Statistics (4QH)
Fall* and Winter Quarters
(formerly IIS 3523)
This course develops statistical models for analysis and prediction of random phenomena. Topics include: review of descriptive statistics and hypothesis testing;

linear models, both regression and ANOVA; chi-squared and non-parametric tests; and introduction to design of experiments. Emphasis will be placed on applying linear models in real life situations. *Prep. MIM 3400.*

MIM 3425 Introduction to Reliability Analysis and Risk Assessment (4QH)
Fall Quarter
(formerly IIS 3525)
Introduction to probability theory, classical and Bayesian statistics useful for reliability analysis of large, complex systems. Bayesian probability encoding of experience data; principles of the methods of risk assessment and reliability analysis including fault trees, decision trees, and reliability block diagrams. Practical applications to industrial operations, e.g., nuclear and chemical plants, military systems, large processing plants, are treated. *Prep. MIM 3400 or permission of instructor.*

MIM 3435 Reliability Engineering and Testing (4QH)
Spring Quarter
(formerly IIS 3535)
This course is intended to acquaint the students with the evolving methodology of reliability as a design parameter. The problems of quantifying, assessing and verifying reliability are studied. Various factors that determine the stress and strength of components and their impact on system reliability are presented. Practical applications, examples, and problems cover a broad range of engineering fields, such as mechanical, electrical, industrial, computer, structures and automatic control systems. *Prep. MIM 3400.*

MIM 3440 Total Quality Control for Engineering (4QH)
As Announced
(formerly IIS 3540)
Principles of Total Quality Control (TQC). Japanese management methods for technologies: manufacturing, electrical, steel, and automobile industries. Seven statistical methods of TQC: histograms, cause and effect diagrams, check sheets, Pareto diagrams, graphs, control charts, and scatter diagrams. Case studies of TQC implementation in technology management. Guest lectures by invited authorities. *Prep. MIM 3400.*

MIM 3503 Simulation Methodology and Applications (4QH)
Fall* and Spring Quarters
(formerly IIS 3503)
Covers when, where and how to use discrete event simulation techniques. Topics include model design, development and validation; tactical and strategic planning considerations in the use of the model; input data reduction; alternative programming languages for implementing models; efficiency in running simulations, and statistical reliability in the design and analysis of simulation experiments. Several special purpose simulation languages are discussed, e.g. SIMSCRIPT, GPSS, and SIMAN. The opportunity to code models in one language is provided. *Prep. MIM 3400.*

MIM 3505 Advanced Simulation Analysis (4QH)
Spring Quarter
(formerly IIS 3505)
The focus of this course is the statistically-based methodology of simulation analysis. Topics covered include: selection of input probability distributions, random number and random variate generation, analysis of output streams, variance reduction techniques and experimental design and optimization. We seek a thorough understanding of the theory underlying these issues and how they relate to the design and execution of statistically valid simulation studies. The level of discussion is state-of-the-art as defined by the latest published research results. In light of this background, an assessment of the effectiveness with which these issues are included in the major simulation languages (e.g., SIMAN, GPSS, SIMSCRIPT) is made. *Prep. MIM 3503.*

MIM 3510 Forecasting (4QH)
Spring Quarter
(formerly IIS 3312)
Statistical forecasting procedures widely used in production planning and inventory control. Topics include introduction to regression analysis and statistical modeling for forecasting and control, moving averages and related methods, exponential smoothing methods, direct smoothing methods, seasonal smoothing models, autoregressive integrated moving average (ARIMA) models, interventional models, adaptive-control forecasting methods, and analysis of forecast errors. Forecasting experience using existing statistical computer programs is emphasized. *Prep. MIM 3423.*

MIM 3512 Inventory Theory (4QH)
Fall Quarter
(formerly IIS 3313)
This course considers the nature and characteristics of inventory systems. It is concerned with techniques of constructing and analyzing mathematical models of inventory systems with a view towards determining

operating policies for such systems. *Prep. MIM 3400 and MIM 3530.*

MIM 3513 Network Analysis and Advanced Linear Programming (4QH)
Winter Quarter
(formerly IIS 3513)
Concepts of advanced linear programming and network algorithms are considered. Topics include: theory of the simplex method, the revised simplex algorithm, simplex for bounded variables, decomposition and column generation methods, complexity of the simplex algorithm and polynomial algorithms for linear programs, minimum cost network flows, network simplex, transportation, assignment and transshipment problems, and algorithms for solving maximal flow, minimum cut and shortest path problems. *Prep. MIM 3530.*

MIM 3514 Logistics, Warehousing, and Scheduling (4QH)
Winter Quarter
(formerly IIS 3314)
The determination of needs and requirements for logistics within large-scale systems and business environments are explored. Measures of logistics including reliability, maintainability, and supportability are examined. Systems maintenance concepts, logistics support analysis, and logistics in system design are covered. Warehousing and scheduling in the context of a business logistics system are introduced. Approaches to examining warehouses and the associated algorithms are considered. *Prep. MIM 3400.*

MIM 3515 Queuing Theory (4QH)
Winter Quarter
(formerly IIS 3515)
Development of stochastic techniques used in queueing theory. Single and multiple server queues. Truncated queues. Complementarity and equivalence in queues. Queueing networks. Emphasis will be placed on theory as well as applications. *Prep. MIM 3531.*

MIM 3522 Systems Engineering Design and Analysis (4QH)
Spring Quarter
(formerly IIS 3522)
Principles of systems modeling and analysis using continuous simulation techniques. Topics include differential equations as system models; Laplace transformations; numerical approximation techniques; stability; steady-state error; control actions; alternative modeling schemes; and validation of system models via continuous simulation techniques. *Prep. Admission to Graduate School and higher level language.*

MIM 3524 Multi-Criteria Decision Making (4QH)
Spring Quarter
(formerly IIS 3524)
Theory, computation and applications of multi-criteria decision making. Topics include techniques for generating noninferior solutions, techniques for finding the best-compromise solution, vector-maximum algorithms, filtering, multiattribute utility functions, analytic hierarchy process, goal programming and interactive methods. *Prep. MIM 3530.*

MIM 3530 Operations Research I (4QH)
Fall and Summer* Quarters
(formerly IIS 3530)
Introduction to the theory and use of deterministic models to represent industrial operations. It includes linear programming and networks. *Prep. Course in linear algebra.*

MIM 3531 Operations Research II (4QH)
Fall* and Winter Quarters
(formerly IIS 3531)
Introduction to theory and use of stochastic models to represent industrial operations. It includes dynamic programming, Markovian models, queueing, and inventory models. *Prep. MIM 3400.*

MIM 3532 Operations Research III (4QH)
Spring Quarter
(formerly IIS 3532)
Important families of mathematical programming problems and optimization methods will be covered. The cutting plane and the branch and bound algorithm for binary and mixed integer programming problems. Introduction to nonlinear programming including unconstrained optimization, the Kuhn-Tucker conditions, gradient methods, separable, quadratic and geometric programming. *Prep. MIM 3530.*

MIM 3600 Theory of Elasticity (4QH)
Winter Quarter
(formerly ME 3120)
Analysis of Cartesian tensors using indicial notation. Stress and strain concepts; point stress and strain; relation to tensor concepts. Governing equations for the determination of stress and displacement distributions in a solid body. Exact solutions of the governing equations for elastic solids. Plane stress and strain problems in rectangular and polar coordinates including thermal stress. Relation of elasticity theory to strength of materials. Torsion of prismatic and axially symmetric bars. Bending of thin flat rectangular and

circular plates. *Prep. Admission to the Graduate School of Engineering.*

MIM 3615 Theory of Plates and Shells (4QH)
Spring Quarter, Odd Years
(formerly ME 3446)

Theory of plates using classical theory (cylindrical bending, rectangular plates, circular plates). The combined effects of bending and in-plane forces. Buckling of plates. Effects of shear deformation and of large deflections. Membrane theory of shells. Analysis of cylindrical shells. General theory of thin elastic shells. Shells of revolution. *Prep. MIM 3600.*

MIM 3620 Mechanics of Composite Materials (4QH)
Winter Quarter, Odd Years
(formerly ME 3455)

Introduction to composite materials. Constitutive relations for anisotropic laminae and mechanical properties. Micromechanics models are used. Laminated composites and effects of stacking sequence. Selected topics include damage in fiber composite sheets. Application to structural response of beams and plates. *Prep. MIM 3600.*

MIM 3625 Advanced Dynamics (4QH)
Fall Quarter, Odd Years
(formerly ME 3140)

Kinematics of particles and rigid bodies including moving reference frames. Modeling and application of fundamental laws of motion. Dynamic response of lumped parameter systems. Lagrange's equations. Applications in two and three dimensions. *Prep. Admission to the Graduate School of Engineering.*

MIM 3630 Vibration Theory and Applications (4QH)
Spring Quarter
(formerly ME 3470)

Laplace transformation techniques; phase-plane diagrams; multiple-degree-of-freedom systems; free and forced vibrations with and without damping. Systems with distributed mass and stiffness. Extensional, torsional and flexural vibrations of bars. *Prep. MIM 3625 or permission of instructor.*

MIM 3650 Automatic Control Engineering (4QH)
Fall Quarter, Even Years
(formerly ME 3464)

Review of continuous-time system modeling and dynamic response, principles of feedback, classical control analysis and design techniques such as root-locus, and frequency-response. State-variable representation and optimal controller and estimator design introduced. Course project: modeling, analysis, and controller design of student-selected system. *Prep. Undergraduate controls course or permission of instructor.*

MIM 3665 Engineering Fracture Mechanics (4QH)
Fall Quarter, Odd Years
(formerly ME 3431)

Fundamentals of brittle fracture; theoretical strength, micro/macro fracture characteristic, Inglis-Griffith theory, applicability of same. Linear elastic fracture mechanics; Orewan/Irwin extension to metals, effective surface tension and relation to fracture toughness, plastic zone size correction; geometry effects on fracture toughness; plane/strain stress fracture toughness, thickness effects. Experimental determination of fracture toughness; slow crack growth "pop in", arrest, R-G curves, compliance techniques for determining elastic energy release rate. Alternate fracture toughness concepts; resistance curve, crack opening displacement, the J integral. Application of fracture mechanics to fatigue. Design methods to minimize risks of catastrophic failure will be emphasized. *Prep. MIM 3600.*

MIM 3675 Advanced Mechanics of Materials (4QH)
Fall Quarter
(formerly ME 3440)

Review of fundamental stress and deformation concepts; strain energy density; introduction to energy methods with application to beams, frames and rings; Ritz method. Beams on elastic foundations. Concept of stability as applied to one and two degree-of-freedom systems. Buckling of bars, frames and rings. *Prep. Admission to the Graduate School of Engineering.*

MIM 3680 Mechanics of Metal Forming for Manufacturing (4QH)
Winter Quarter, Even Years

This course will provide an introduction to the topic of the finite deformation of solids. The most common metal forming techniques will be presented. Experimental and theoretical constitutive descriptions of the large deformation of metals will be discussed including: von Mises yield surface, isotropic and kinematic hardening, Prandtl-Reuss constitutive laws, and viscoplasticity. They will then be applied to common metal forming operations including: rolling, forging and sheet metal forming. Emphasis will be placed on the use of numerical techniques and especially finite elements to solve the complicated boundary value problems. Each student will use a commercial finite

element package to solve and interpret a metal forming problem. *Prep. MIM 3600.*

MIM 3690 The Finite Element Method (4QH)
Spring Quarter
(formerly ME 3480)
Introduction to the finite element method. Variational formulations; simple interpolation functions and element stiffness matrices. Triangular and rectangular elements. Assembly technique and constraining of resulting equations. Elementary applications. Isoparametic element formulation of higher order and three dimensional elements. Rayleigh-Ritz and Galerkin formulations. Applications of finite element theory to mechanical engineering problems in the areas of solid mechanics, heat transfer, and fluid mechanics. The use of a finite element general purpose commercial package is included. *Prep. MIM 3000 or permission of instructor.*

MIM 3695 Experimental Techniques in Design (4QH)
Winter Quarter, Odd Years
(formerly ME 3520)
In mechanical engineering, there is usually a need for verification of material properties, response simulation of the designed element, proof tests, and nondestructive testing of components. Design case histories will be utilized in defining appropriate experimentation needed for verification, simulation, proof tests, and inspection. These experiments may include, though they are limited to, tensile, fatigue, fracture toughness, vibration analysis, thermofluid analysis, and nondestructive testing. In this regard, the course will discuss the techniques associated with these experiments and methods of optimization of data and its acquisition. *Prep. Admission to the Graduate School of Engineering.*

MIM 3700 General Thermodynamics (4QH)
Winter Quarter
(formerly ME 3200)
Fundamentals of equilibrium thermodynamics will be examined. Topics may include: work, energy, heat, temperature, available energy, entropy, first and second law of thermodynamics, simple systems, closed and open systems, availability loss and irreversibility, heat engines, multicomponent systems, mixtures of gases, chemical reactions and chemical equilibrium. *Prep. Admission to the Graduate School of Engineering.*

MIM 3710 Statistical Thermodynamics (4QH)
Spring Quarter, Even Years
(formerly ME 3580)
An introductory course in statistical thermodynamics for Mechanical Engineers designed to provide insight into the laws of classical thermodynamics and the behavior of substances. Topics to be covered include: Introduction to probability; elementary kinetic theory of an ideal gas including the distribution of molecular velocities and the mean free path treatment of transport properties; classical statistics of independent particles, equipartition of energy, the partition function and laws of thermodynamics; some results from quantum mechanics, quantum statistics of independent particles; applications to gases; introduction to ensembles and systems of interacting particles. *Prep. MIM 3000 and MIM 3700 or equivalent.*

MIM 3720 Heat Conduction and Thermal Radiation (4QH)
Winter Quarter
(formerly ME 3540)
Topics covered include: Formulation of steady and unsteady state one- and multi-dimensional heat conduction problems, solution techniques for linear problems including the method of separation of variables, Laplace transforms and integral transforms, approximate analytical methods, phase change problems, non-linear problems, nature of thermal radiation, Blackbody and radiation from a blackbody, radiation from a non-black surface element, radiative exchange among surfaces separated by a non-participating medium, and interaction of radiation with other modes of heat transfer in non-participating media. *Prep. MIM 3000 and undergraduate heat transfer.*

MIM 3725 Convective Heat Transfer (4QH)
Fall Quarter
(formerly ME 3544)
Topics covered include: Fundamental equations of convective heat transfer, heat transfer in incompressible external laminar boundary layers, integral boundary layer equations, laminar forced convection in internal flows, turbulent forced convection in internal and external flows, analogies between heat and momentum transfer: the Reynolds, Taylor and Martinelli analogies; natural convection, heat transfer in high-speed flow, and transient forced convection. *Prep. MIM 3750 and MIM 3720 or permission of instructor.*

MIM 3730 Radiative Transfer (4QH)
Spring Quarter, Even Years
(formerly ME 3548)
Topics covered include: Electromagnetic background, fundamentals of radiation in absorbing, emitting and scattering media, equation of radiative transfer, methods of solution of the equation of radiative transfer, pure radiative transfer in participating media, and interaction of radiation with conduction and/or convection. *Prep. MIM 3720.*

MIM 3735 Solar Thermal Engineering I (2QH)
As Announced
(formerly ME 3351)
A model is developed for the hourly direct and diffuse radiation under a cover of scattered clouds and the transmission and absorption of this radiation by passive and active systems. The design of air heating systems and the storage of the collected energy by a pebble-bed are considered, as well as elements of heat exchanger design. A study of the economics of a domestic water and/or space heating system is made using f-chart analysis. *Prep. CHE 3660, Solar Energy Thermal Processes or equivalent background.*

MIM 3740 Heat Transfer Processes in Microelectronic Devices (4QH)
Spring Quarter
Discussion and development of state-of-the-art methods used to predict the heat transfer rates from microelectronic devices and packages and to simulate transport phenomena in manufacturing processes associated with microelectronic devices. Topics will be selected from the current literature and may include use of latent heat reservoirs, boiling jet impingement cooling, control volume approaches to extended surfaces, calculation of thermal contact conductances and natural convection in enclosures. Simulation of laser assisted thermophoretic deposition and laser cladding processes will also be developed. *Prep. MIM 3000 (or equivalent) and undergraduate heat transfer or permission of instructor.*

MIM 3750 Essentials of Fluid Dynamics (4QH)
Fall Quarter
(formerly ME 3210)
A fundamental course in fluid dynamics designed to prepare the student for more advanced courses in the thermofluids curriculum while providing a strong background in fluid mechanics. Topics to be covered may include: Cartesian tensors; differential and integral formulation of the equations of conservation of mass, momentum and energy; molecular and continuum transport phenomena; the Navier-Stokes equations; vorticity; inviscid, incompressible flow, the velocity potential and Bernoulli's equation; viscous incompressible flow; the stream function; some exact solutions; energy equation including heat conduction and viscous dissipation. *Prep. Admission to the Graduate School of Engineering.*

MIM 3755 Two Phase Flow (4QH)
As Announced
(formerly ME 3552)
The basic concepts of heat and mass transfer associated with phase change and multi-phase flows are covered. Some of the specific subjects to be discussed are: boiling heat transfer (nucleate boiling, film boiling and bubble dynamics); evaporation and condensation; and liquid-gas two phase flow and gas-solid and liquid-solid two phase flows. *Prep. MIM 3000 (or equivalent) and undergraduate heat transfer.*

MIM 3760 Viscous Flow (4QH)
Winter Quarter, Odd Years
(formerly ME 3560)
Topics covered are: Review of conservation of mass, momentum, and energy for compressible viscous flow, discussion of the mathematical character of the basic equations and analysis of some exact solutions, investigation of low Reynolds number flow, exact and approximate approaches to laminar boundary layers in high Reynolds number flows, stability of laminar flows and the transition to turbulence, treatment of incompressible turbulent mean flow; internal and external flows, and extensions to compressible boundary layers. *Prep. MIM 3000 and MIM 3750.*

MIM 3765 Gas Dynamics (4QH)
Spring Quarter, Odd Years
(formerly ME 3564)
The consequences of fluid compressibility are studied. Shock waves and the theory of characteristics are discussed with specific consideration given to two-dimensional steady flows and one-dimensional unsteady flows. Additional topics may include axially symmetric steady flow, small perturbation theory, similarity rules, the hodograph method, or some aspects of physical acoustics. *Prep. MIM 3750.*

MIM 3770 Computational Fluid Dynamics with Heat Transfer (4QH)
Spring Quarter
(formerly ME 3568)
Topics covered include: Finite difference methods for solving partial differential equations with particular emphasis on the equations of fluid dynamics and convective heat transfer, integral methods for boundary layers and their coupling to potential flow solutions, use of coordinate transformations and body-

oriented coordinate systems, and application of superposition techniques in convective heat transfer problems. *Prep. MIM 3750 and MIM 3010.*

MIM 3775 Turbomachinery Design (4QH)
As Announced
(formerly ME 3360)
Preliminary design methods and analytical tools applicable to turbomachinery are presented. Design criteria and performance characteristics at design and off-design operating conditions are discussed for several important types of turbomachinery. Axial flow compressors and turbines (gas and steam) are studied in some depth, including topics such as compressor surge, turbine blade cooling, and steam wetness effects. Centrifugal compressors, radial inflow turbine, pumps, fans, and water turbines are also studied. Turbomachinery mechanical design limitations are discussed. The use of empirical data on blade cascade performance in blade selection is examined. Numerical methods of analyzing two- and three-dimensional flows in turbomachinery (e.g., conformal transformation and streamline curvature) are presented. Two in-depth design projects are assigned. *Prep. Admission to the Graduate School of Engineering, including undergraduate preparation in fluid mechanics and thermodynamics.*

MIM 3780 Aerosol Mechanics (4QH)
As Announced
(formerly ME 3572)
This course studies the behavior of ultrafine particles from both microscopic and macroscopic viewpoints. First the microscopic origins of aerosol transport phenomena are discussed including Brownian diffusion, drag, thermophoresis, condensation and evaporation. This is followed by a discussion of deposition processes for monodisperse aerosols, distribution functions for polydisperse aerosols, the general dynamic equation and methods of solution, homogeneous nucleation, and coagulation. Industrial applications will be introduced where appropriate. *Prep. MIM 3000, MIM 3700, MIM 3750 or permission of instructor.*

MIM 3785 Turbulent Flow (4QH)
As Announced
(formerly ME 3574)
Discussion of flow and transport with emphasis on engineering methods. Generation and dissipation of turbulence, fluctuations and time-averaging, Reynolds stresses and turbulent fluxes, closure models for free and bounded shear flows, models employed for practical flows including k-E and algebraic-stress models; introduction to large eddy and direct simulation; and introduction to numerical modeling of turbulent flows. *Prep. MIM 3750 or permission of instructor.*

MIM 3790 Macroscopic Transport in Materials Processing (4QH)
As Announced
(formerly ME 3576)
Principles of mathematical and physical modeling of the processing of primary and electronic materials. Practical examples will include continuous casting, rheocasting, metal-matrix composites, thermal spraying, magnetohydrodynamics, microgravity processing, growth of semi-conductor crystals and chemical vapor deposition. Transport equations will be discussed as tools of mathematical models and similarity criteria as tools of physical models. Topics will include Newtonian and non-Newtonian fluid mechanics, multi-phase flow, dimensionless numbers, conductive and convective heat transfer, thermal radiation, diffusion and mass transfer with chemical reaction, order-of-magnitude analysis, intelligent processing techniques. *Prep. Undergraduate heat transfer or permission of instructor.*

MIM 3792 Fundamentals of Combustion (4QH)
Fall Quarter, Even Years
(formerly ME 3584)
Comprehensive treatment of the problems involved in the combustion of liquid, gaseous, and solid fuels in both laminar and turbulent flow. The fundamentals of chemical kinetics will be discussed. The equations for the transport of mass, momentum, and energy with chemically reacting gases will be examined. Topics will include diffusion and premixed flames, combustion of droplets and sprays, and gasification and combustion of coal. *Prep. MIM 3700.*

MIM 3795 Combustion and Air Pollution (4QH)
Fall Quarter, Odd Years
(formerly ME 3588)
This course deals with the formation of pollutants during combustion processes and their subsequent transformations in the atmosphere. Emphasis will be placed on the effects of design and operating parameters of combustion devices on the nature and composition of exhaust gases, improvements, post-combustion treatment of effluent gases, atmospheric chemistry, and atmospheric transport of pollutants, smog formation, acid rain, ozone formation and destruction. *Prep. Undergraduate course in thermodynamics, heat transfer and fluid mechanics, or permission of instructor.*

MIM 3800 Strengthening Mechanisms (4QH)
As Announced
(formerly ME 3252)
Dislocation theory; including such topics as dislocation stress fields, self-energy, velocity, interactions mechanisms, image forces, and theories of yielding, mechanical behavior of metals. Application of dislocation theory to micro-plasticity, strain hardening, strengthening mechanisms and creep. *Prep. A recent introduction to materials science course.*

MIM 3806 Phase Transformations (4QH)
As Announced
Considers the different types of phase transformations that occur in metals and alloys in relation to theory and practice. The first part consists of a review of thermodynamics, with emphasis on the properties of solutions, their relation to phase diagrams, and the theory of diffusion. The student will then learn how to related these fundamentals to the thermodynamics and kinetics of phase transformations and understand how phase transformations alter the microstructure of materials. Both diffusional and diffusionless phase transformations are covered. Examples of applications to materials processing and manufacturing are presented. *Prep. MIM 3820.*

MIM 3815 Powder Metallurgy (2QH)
Fall Quarter
(formerly ME 3620)
Powder characteristics and methods of manufacture. Powder pressing: packing, interparticle bonding, effects of pressure; principles of sintering; characteristics and properties of products made from powdered materials. *Prep. A recent introductory materials science course.*

MIM 3820 Thermodynamics of Materials (4QH)
Winter Quarter
(formerly ME 3264)
Basic materials thermodynamics encompassing first, second, and third laws, entropy, enthalpy, and free energy. Emphasis on solutions, activity, activity coefficients, the phase rule and applications to some materials problems. *Prep. Undergraduate Thermodynamics.*

MIM 3825 Electronic Behavior I (4QH)
Fall Quarter
(formerly ME 3272)
Electronic principles underlying the structure and properties of solid materials; the relationships of these principles to the properties and to applications in structures and device; both macroscopic-phenomenological and electronic-molecular approaches will be used. Materials will include metals and alloys, semiconductors, and dielectrics. Typical subjects are electronic structures, band theory, thermal properties, and electrical conductivity. *Prep. A recent introductory materials science course.*

MIM 3830 Electronic Behavior II (2QH)
Winter Quarter
(formerly ME 3602)
Continuation of MIM 3825 into magnetic, dielectric, and optical properties. *Prep. MIM 3825.*

MIM 3835 Corrosion I (2QH)
As Announced
(formerly ME 3603)
The study of the thermodynamics of corrosion and corrosion reactions both in aqueous and non-aqueous environments. Topics will include thermodynamics, kinetics, and the effects of environment and physical metallurgy. *Prep. Admission to the Graduate School of Engineering.*

MIM 3839 Environmental Issues in Manufacturing and Product Use (4QH)
As Announced
This course explores environmental and economic aspects of different materials used in a product throughout the life cycle. Concepts of industrial ecology, life cycle analysis and technical cost modeling are introduced. Students work in teams to analyze case studies of specific products fabricated using metals, ceramics, polymers and paper. These case studies compare cost, energy, resources used and emissions generated through the mining, refining, manufacture, use and disposal stages of the product life cycle. Issues in legislation - manufacturer take-back, packaging, ecolabeling- and issues in disposal strategies - landfill, incineration, reuse and recycling - are debated. Difficulties associated with environmental impact assessments, and the development of decision analysis tools to weigh the tradeoffs in technical, economic and environmental performance are discussed. *Prep. Admission to the Graduate School of Engineering.*

MIM 3840 Corrosion II (2QH)
As Announced
(formerly ME 3604)
Continuation of MIM 3835. *Prep. MIM 3835.*

MIM 3845 Electronic Materials (4QH)
Spring Quarter
(formerly ME 3607)
Generic techniques for fabrication and processing, and the resulting structure-property relationships, are presented for materials utilized in electronics.

Typically included are: bulk single crystals, thin films, metals, semi-conductors, and insulators. *Prep. MIM 3825.*

MIM 3850 Diffraction Methods in Materials Science (4QH)
As Announced
(formerly ME 3609)
Embodies the material in MIM 3855 and MIM 3859. *Prep. A recent materials science course.*

MIM 3855 Introduction to Diffraction Methods in Material Science (2QH)
As Announced
(formerly ME 3610)
General principles of the diffraction by materials of short wave length radiations; (such as x-ray, electrons, and thermal neutrons) are studied with emphasis on the understanding of the similarities and differences of the different radiations when applied to the study of the structures of crystalline and non-crystalline materials. *Prep. A recent introductory materials science course.*

MIM 3859 Diffraction Methods in Material Science (2QH)
As Announced
(formerly ME 3611)
Continuation of MIM 3855 with emphasis on the experimental methods and applications. This includes: choice of radiation, introduction to instrumentation, sample preparation, methods of detection and recording of the diffracted radiation, analysis, interpretation and use of the results. *Prep. MIM 3855.*

MIM 3860 Ceramics Processing I (2QH)
As Announced
(formerly ME 3625)
Introduction to ceramic fabrication processes. Characteristics of vitreous and crystalline solids, structural imperfections, and atomic mobility. Phase equilibria, nucleation, crystal growth, solid-state reactions, non-equilibrium phases, and effects on the resulting microstructure of ceramics. *Prep. A recent introductory materials science course, physical chemistry or solid state physics.*

MIM 3865 Ceramics Processing II (2QH)
As Announced
(formerly ME3626)
Discussion of effects of composition and microstructure on the thermal, mechanical, optical, electrical, and magnetic properties of ceramic materials. *Prep. MIM 3860.*

MIM 3869 Ceramics Processing (4QH)
As Announced
(formerly ME 3627)
Embodies the material in MIM 3860 and MIM 3865. *Prep A recent introductory materials science course, physical chemistry, or solid state physics.*

MIM 3870 The Structure and Properties of Polymeric Materials I (2QH)
As Announced
(formerly ME 3630)
Introduction to the organic chemistry of polymers, effect of chemical composition on structure, melting point and glass transition temperature, polymer characterization and degradation, thermodynamics of polymers. *Prep. Undergraduate materials science course.*

MIM 3875 The Structure and Properties of Polymeric Materials II (2QH)
As Announced
(formerly ME 3631)
Rheology and mechanical behavior of polymers, analysis and testing, effects of processing on structure and physical properties, industrial polymers, resin base composites. *Prep. MIM 3870.*

MIM 3880 The Structure and Properties of Polymeric Materials (4QH)
As Announced
(formerly ME 3632)
Embodies the material in MIM 3870 and MIM 3875. *Prep. Undergraduate materials science course.*

MIM 3900 Independent Study (2QH)
Any Quarter
(formerly IIS 3801 and ME 3850)
Theoretical or experimental work under individual faculty supervision. *Prep. Approval of Department faculty.*

MIM 3905 Independent Study (4QH)
Any Quarter
(formerly IIS 3802)

MIM 3910 Special Topics (2QH)
Any Quarter
(formerly IIS 3806 and ME 3853)
Topics of interest to the staff member conducting this class are presented for advanced study. *Prep. Approval of department faculty.*

MIM 3915 Special Topics (4QH)
Any Quarter
(formerly IIS 3804 and ME 3854)
Topics of interest to the staff member conducting this class are presented for advanced study. *Prep. Permission of Department faculty.*

MIM 3925 Thesis (Master of Science Degree) (2QH)
Any Quarter
(formerly IIS 3842, IIS 3862 and ME 3862)
Analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. First-year students must attend a graduate seminar program which will introduce the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Successful completion of the seminar program is required. *Prep. Admission to the Graduate School of Engineering.*

MIM 3930 Thesis (Master of Science Degree) (4QH)
Any Quarter
(formerly IIS 3841, IIS 3861, and ME 3861)
Analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. First-year students must attend a graduate seminar program which will introduce the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Successful completion of the seminar program is required. *Prep. Admission to the Graduate School of Engineering.*

MIM 3935 Thesis (Master of Science Degree) (8QH)
Any Quarter
(formerly IIS 3840, IIS 3860, and ME 3860)
Analytical and/or experimental work conducted under the direction of the faculty in fulfillment of the requirements for the degree. First-year students must attend a graduate seminar program which will introduce the students to the methods of choosing a research topic, conducting research, and preparing a thesis. Successful completion of the seminar program is required. *Prep. Admission to the Graduate School of Engineering.*

MIM 3940 Master's Degree Continuation (0QH)
Any Quarter
(formerly IIS 3798 and ME 3798)

MIM 3945 Master's Degree Project (4QH)
(formerly IIS 3850)
Prep. Approval of advisor.

MIM 3980 Doctoral Reading (2QH)
Any Quarter
(formerly ME 3856)
Material approved by the candidate's advisor (only S or F grades will be assigned for this course). *Prep. Passing of PhD Qualifying Exam.*

MIM 3985 Dissertation (PhD) Degree (0QH)
Any Quarter
(formerly ME 3880)

MIM 3990 PhD Continuation (0QH)
Any Quarter
(formerly IIS 3799 and ME 3799)

Academic Policies and Procedures

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A - Course Registration and Withdrawals

A1 - Program Approvals

The curricula of the degree programs are given under the respective department headings. Descriptions of courses are given so that students may obtain a general view of the course coverage. Preparatory courses may be required of students upon their acceptance. Not all courses are offered every year, but the courses are arranged in such a manner that students may make continuous progress toward their degrees. The Graduate School of Engineering issues a circular which gives the expected course offerings for the following academic year and the times at which they will meet. At the time of Fall Orientation, each full-time student is expected to develop, with the assistance of the program advisor or the department's Graduate Officer, a complete program of study. Any subsequent changes must be approved by the advisor or the Graduate Officer.

A2 - Course Selections

Minimum Required Number of Courses

Full-time students in the Graduate School of Engineering must enroll on a continuous basis and maintain a minimum of 12 quarter hours of credit per quarter. However, if one of the following cases apply, then a graduate student enrolling for a minimum of 8 quarter hours of credit is considered full-time:

a) If the student is an international student for whom English is a second language.
b) If the student holds a Northeastern University Tuition Assistantship (NUTA).

Students who hold a Stipended Graduate Assistantship are considered full-time if enrolled for a minimum of 6 quarter hours of credit. All graduate students who are registered in continuation or enrolled in doctoral research are considered full-time. Part-time students may register for a maximum of 6 quarter hours of credit per quarter.

Choosing Courses

In selecting courses, full-time students should follow the schedule approved by their advisors or the department's assigned Graduate Officer. Part-time students should follow the outlines presented in the departmental program sections and confer with the program advisors or the department's assigned Graduate Officer for additional assistance as needed.

Courses other than core courses are offered according to the demand and the availability of faculty for specific areas. Students should pre-select courses whenever possible and plan to take them when offered, maintaining flexibility with alternate courses in mind. There is no guarantee that any particular course will be offered, but the Graduate School of Engineering will do everything possible to assure continuity of programs.

To register for a course offered by other Graduate Schools at Northeastern, approval from the Graduate School of Engineering must be obtained before a student can petition the other graduate program. Refer to the sub-section "Non-Graduate Engineering Courses" under Section D for further details.

Students who need assistance in course selection, course sequencing, waivers and transfer credits should contact their advisors or the department's assigned Graduate Officer or the Graduate School of Engineering. Additional information is provided under Administrative Procedures.

A3 - Thesis Continuation

Students who have not completed their thesis after having registered for the specified number of thesis credits must register for Thesis Continuation each subsequent quarter during the academic year until the thesis is completed. Thesis continuation carries no credit, but will appear on the student's transcript along with the appropriate grade for each quarter of registration. The continuation fee is one-half the tuition cost of one quarter hour for Master of Science and the cost of one quarter hour for Doctoral Degrees. Students who fail to register for Thesis Continuation will be charged retroactively at the time of degree conferral for any quarters in which they did not register for their continuation fee.

A4 - Registration Procedures

Registration is mandatory. Any student who has failed to register properly before the end of the fifth week of classes will not receive a grade at the end of the quarter, even if the course work has been completed.

PhD students must register for course work or dissertation as approved by their advisors or the departmental Graduate Officer. After commencing studies, registration must be continuous unless withdrawal is allowed by the committee in charge of the degree program in which the student is enrolled.

All registration for regularly scheduled courses is conducted by telephone commencing several weeks prior to the start of each academic term. Instructions for the telephone registration procedures are available in the quarterly *Graduate Schools Course Offerings Booklet* published by the Registrar's Office. Late telephone registration will occur during the first week of each quarter. Course enrollment is granted on a first-come, first-served basis, and past experience indicates that many courses close early in the registration process.

For adding courses following the telephone registration period, students must obtain a late registration form from the Graduate School of Engineering Office. A student wishing to drop a course after the end of telephone registration must go to the Office of the Registrar or to the Burlington Campus to complete an add/drop form.

A5 - Course Withdrawal Procedures

In order to withdraw from a course, a student must fill out an official withdrawal form obtained at the Registrar's Office or at the Burlington Campus office. Withdrawals may be made through the ninth week of the quarter. However, withdrawals which are made after the fifth week of the quarter will be recorded with a "W" on the student's transcript.

Ceasing to attend a class, or simply notifying the instructor of intent to withdraw, does not constitute an official withdrawal. Students will be charged for the course tuition and will be subject to grade of "F" should they fail to officially withdraw.

Tuition refunds are granted only on the basis of the date on which the form is filed with the Registrar's Office. Students should keep their copy of the course withdrawal form to avoid any possibility of error. The Bursar's Office will credit a student's account or refund tuition in accordance with the following schedule:

Official Withdrawal Filed Within	% Tuition Refunded
First week of quarter	100%
Second week of quarter	75%
Third week of quarter	50%
Fourth week of quarter	25%

Requests for withdrawal from a course after the ninth week of the quarter may be submitted in writing to the Director of the Graduate School.

A6 - Common Registration Problems and Policies

Students who use telephone registration will receive confirmation of their courses by mail.

Class sizes are controlled by the Registrar and set by the Director of The Graduate School of Engineering in consultation with the departments. The number of students enrolled in each class is limited to permit effective teaching at the graduate level. The University reserves the right to cancel, postpone, combine, or modify any course.

To register properly for any closed course, a student must obtain a *Closed Course Registration Form* from the Graduate School of Engineering and submit it to the Registrar's Office. All appeals to enter a closed course must be submitted to the Director of the Graduate School for approval. Such permission is normally granted in cases where 1) the student has a prospective date of graduation the following June, the course is essential to his or her program, and the course cannot be taken in any of the following quarters, or 2) the student has successfully completed the first part of a sequential course. The addition of the student's name to the class list by the instructor does not constitute registration and will not entitle the student to a grade even if all the course work is completed.

Due to last minute scheduling changes, the Graduate School will occasionally substitute faculty or change times for the class meetings after registration has begun. Any student who initially registered for the original course will automatically be registered for the new version should no major schedule conflicts be apparent. Otherwise, all registered students will be contacted for alternatives. Wherever possible, the Graduate School will attempt to satisfy these students' first options. Once the student has received notification of a time change and when the alternative results in a schedule conflict the student is responsible for making any registration changes.

Graduate Assistants must follow standard procedures for registering, dropping and adding courses. Registration conflicts with regard to work or teaching schedules must be resolved by the Graduate School, not the Registrar's Office.

Students are asked not to register for an excessive number of courses or double sections with the intention of dropping half or more of the courses during the first week of classes. "Double Section" requests will not be processed by the Registrar's Office. Over-registering complicates course and room scheduling, closes courses prematurely to genuinely interested students, and increases the number of changes and thus the chance of error. Students who abuse the registration process will jeopardize their program status.

As described in the Administrative Procedures section, course credits earned in the Graduate School of Engineering are valid for a maximum of seven years in the Master of Science degree program, and up to five years in the Engineer Degree and PhD programs (once PhD degree candidacy has been established).

All students who change their address, name or phone number during their enrollment in the Graduate School of Engineering should inform the Registrar and Graduate Engineering Office separately and in writing.

Any student who is financially withdrawn prior to the start of any given quarter must clear his or her financial obligation by the end of the fifth week of the quarter in order to receive academic

credit. No grades will be processed for any student who remains financially withdrawn after the fifth week of any given quarter.

A7 - Student ID Cards and Parking Permits

Full-time students receive photo ID cards during the Fall Orientation week. Part-time students will receive their ID cards (valid only in the current quarter) in the mail approximately one week before classes begin. Full-time students who lose their ID cards can get a replacement through the Public Safety Office in Forsyth Hall. Part-time students who lose their ID cards should contact the Registrar's Office.

Parking stickers are obtained from the Traffic Office by submitting a cashier's payment card, car registration, and proof that you have registered (ID card or facsimile). Parking space is available on a first-come, first-served basis.

B - Grading System

The student's performance in graduate courses will be graded according to the following numerical equivalents:

A	(4.0)	This grade is given to those students whose performance in the course has been of very high graduate caliber.
A-	(3.667)	
B+	(3.333)	
B	(3.0)	This grade is given to those students whose performance has been at a satisfactory level.
B-	(2.667)	
C+	(2.333)	
C	(2.0)	This grade is given to those students whose performance in the course is not at the level expected in graduate work.
C-	(1.667)	
F	(0)	Failure
I		Incomplete
IP		In Progress (Intended for courses such as Senior Thesis or a project which extends over several quarters)
NE		Not Enrolled: Did not attend after the date of record; will not appear on the student transcript.
S		Satisfactory (Pass/Fail Basis; counts toward total degree requirements)
U		Unsatisfactory (Pass/Fail Basis)
X		Incomplete (Pass/Fail Basis)
L or AUD		Audit (No Credit Given; Not valid for Undergraduate Day Programs)

Individual faculty members may choose not to use the plus and minus designations. If they elect to use the whole letters only, they must announce this to the class at the beginning of the quarter.

C - Academic Standards and Degree Requirements

C1 - Academic Classifications

Students initially entering the Graduate School are classified into one of four groups according to their admission qualifications:

1. **Regular students** are those who meet in full all admittance criteria based on the standards established by the Committee on Graduate Study in Engineering.
2. **Provisional students** are those who do not qualify for regular admission based on the standards established. In order to continue in the Graduate School of Engineering and be reclassified as a regular student, provisional students must obtain a 3.000 grade point average in their first twelve quarter hours of course work and fulfill any specified prerequisites.
3. **Special students** are those who are not pursuing a specific degree program. Special students must satisfy the admission standards and perform work of a satisfactory level in order to continue as Special Students. They are allowed to enroll in a maximum of 12 quarter hours of graduate credits.
4. **Transitional students** are those who are of acceptable quality but are deficient in their undergraduate preparation with respect to the program of graduate study they would like to pursue. Students with this classification are required to complete a transitional program of study either before or concurrently with their graduate program as specified by the graduate school. Transitional students must maintain a 3.000 grade point average in their transitional program to be reclassified as regular students.

C2 - Academic Requirements

All students must satisfactorily complete an approved program of correlated work of graduate caliber and such other study as may be required by the department in which he or she is registered. Regardless of classification, any student whose record is not satisfactory may be withdrawn from the Graduate School of Engineering.

To qualify for any degree from the Graduate School of Engineering a student must have a grade point average of not less than 3.000 with no more than 12 credits below a B- in all courses applied towards the degree, exclusive of prerequisite courses. The Committee on Graduate Study in Engineering allows eight quarter hours of credit to be taken beyond the stated minimum degree requirements to repeat failed required courses or substitute for elective courses in order to obtain the required 3.000 average for the completion of degree requirements. Within the above limitations for extra or repeated courses, a required course for which a grade of F is received must be repeated with a grade of C- or better.

With the approval of the department and the Graduate School of Engineering, enrolled students are allowed to audit a course. While no credit will be given for an audit, audits do appear on the student's transcript. Registration changes from an audit to a graded status in a course may not be made after the first day of classes.

C3 - Changes in Requirements

The continuing development of the Graduate School of Engineering forces frequent revision of curricula and in every new bulletin some improvements are indicated. Students are expected to complete the academic requirements of the program as described in the catalogue published in the year studies were begun. However, they may elect to pursue the revised program requirements upon departmental approval.

C4 - Class Hours and Credits

All credits are entered as quarter hours. A quarter hour of credit is roughly equivalent to three fourths of a semester hour credit. All classes meet on a quarter basis. In the summer session, some classes meet for two, six-week periods. The academic calendar in the Graduate Student Handbook should be consulted for the opening and closing dates of each academic quarter.

C5 - Code of Student Conduct

The Graduate School of Engineering will take immediate disciplinary action in all cases where a student has failed to adhere to the University rules and regulations for proper student conduct. Among others, cheating, fabrication, facilitating academic dishonesty, and plagiarism are considered violations which may result in immediate dismissal from the Graduate Engineering program. Students should refer to the University's *Undergraduate and Graduate Student Handbook* for additional information.

C6 - Continuity of Program

Students are expected to maintain continuous progress toward their intended degree. A student who has attained 8 quarter hours of incomplete (I) grades and/or withdrawals may, at the discretion of the Director of the Graduate School of Engineering, be withdrawn for failure to show continuous progress toward the degree.

C7 - Filing for the Degree

Each student who plans to graduate either in June or September must submit to the Registrar's Office a completed commencement card in the fall quarter of the academic year in which the student expects to graduate. If the deadline for filing is not met, there is no assurance that the degree will be awarded that year. The commencement card is supplied and is mailed to all active students during the fall quarter or is available in the Registrar's Office. It is the student's responsibility to make sure that degree requirements have been met, subject to confirmation by the Graduate School of Engineering.

C8 - Incomplete Grades

The I grade will be changed to a letter grade when the deficiency which led to the I is corrected to the satisfaction of and in the manner prescribed by the instructor in the course. The period for clearing such a grade will be restricted to one calendar year from the date of its first being recorded on the student's permanent record.

C9 - Prerequisite/Advanced Undergraduate Courses

Prerequisite courses will not be given credit toward degree requirements unless expressly stated by the individual departments. Advanced undergraduate courses are sometimes approved for graduate degree credit. A request must be made on a Graduate Engineering Petition form and submitted to the Graduate Engineering office for approval. (See the ***Administrative Procedures*** section.) The maximum number of prerequisite credits allowed is determined by each academic department and is specified under the course descriptions for each department.

C10 - Time Limitations

Course credits earned in the program of graduate study, or accepted by transfer, are valid for a maximum of seven academic years in the Master of Science degree programs, up to five years in the

Engineer Degree programs, and up to five years in the PhD programs once degree candidacy has been established. (Refer to ***Administrative Procedures*** section under *Time Limit Extension* petitions.)

D - Administrative Procedures

D1 - Change in Major (1)

A change of major area of concentration within the same department may be done on a petition form obtained from the Graduate Engineering office. The completed petition, along with an unofficial transcript of your graduate work, should be presented to your advisor or the Department's assigned Graduate Officer for his/her approval. All of these materials are then filed with the Graduate Engineering office for final approval and changing of your major code with the Registrar's Office.

D2 - Change in Status Classification(1)

A change of status from full-time to part-time in the same program may be done by filing a completed petition with the Graduate Engineering office. No advisor's signature is needed. Due to immigration regulations, students on an F-1 or J-1 visa cannot request part-time status. If you are having academic difficulties, the Graduate Engineering School will recommend a remedial course of action for you.

To change status from part-time to full-time in the same program, you will need to have completed a minimum of 12 QH with at least a 3.000 grade point average. Present a completed petition and unofficial graduate engineering transcript to your advisor or the Department's assigned Graduate Officer for approval. All of these materials are then filed with the Graduate Engineering Office for final approval and changing of your status code with the Registrar's Office.

D3 - Course Substitution (2)

A course substitution is the replacement of a graduate level course already taken with an equivalent graduate level course. The Registrar's Office will automatically designate "Repeat" by a course when you retake the same course. However, when a two-part sequence is taken to replace the four quarter hour equivalent, a special request from the Graduate Engineering office has to be made to the Registrar's Office. In order to have "Substitution" noted by the course on your transcript, you need to file a completed petition with an unofficial transcript and your advisor's or the Department's assigned Graduate Officer's approval. After the final approval by the director or his/her designee, the Graduate Engineering office will then notify the Registrar.

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(1) Please Note: a change of major or status into a different department requires re-application. This can be done by requesting, in writing, the Graduate Engineering office to bring your file before the new department's Admission Committee for review. An unofficial graduate engineering transcript, and any other materials needed, should be provided by you to the Graduate Engineering Office.

(2) Please Note: There is an eight-quarter hour limitation on the number of courses you may repeat or substitute. Also. when the notation of "Repeat" or "Substitute" is beside a course on your transcript, the course's grade is no longer calculated into your overall grade point average.

D4- Course Waiver

A course waiver is the replacement of a required course not yet taken in your degree program with an alternative course. To do this, submit a completed petition and unofficial transcript, with the reason

for your request, to your advisor or the Department's assigned Graduate Officer for approval. All of these petitions are then filed with the Graduate Engineering office for final approval.

D5 - Non-Graduate Engineering Courses

To request that an advanced undergraduate engineering course be applied to your graduate degree program, you will need to submit a completed petition with your advisor or the Department's assigned Graduate Officer for approval. With your petition you must submit all the necessary documents, including an unofficial transcript of both the undergraduate course (if already taken) and graduate courses, to support your request. After final approval by the Director of the Graduate School, the course and its grade will be used toward your graduate degree requirements. There is a four quarter hour limit on the number of undergraduate credit hours which may be used for the graduate degree.

In order to receive credit for graduate courses at Northeastern outside of the School of Engineering, you will need to obtain approval from the Graduate Engineering office. Submit a completed petition, including an unofficial transcript, with your advisor or the Department's assigned Graduate Officer for approval. Then, if approved, take your copy of the petition to the graduate school in which the desired course is offered. Usually, you will need to complete a different type of petition for that graduate school at least four weeks prior to the quarter in which the course is being offered. Your copy of the Graduate Engineering petition is verification of approval, and will designate if the non-engineering graduate course is to be applied toward your degree. Interdisciplinary degree students are not required to follow this procedure when the courses are considered part of the degree program.

D6 - Thesis

Instructions for the preparation of a thesis are available from the Graduate School office, and include proper formatting and procedures for depositing the thesis in Snell Library. The thesis topic is developed with your advisor and the final thesis is approved in accordance with the regulations of the Graduate School of Engineering outlined in the instructions.

D7 - Time Limit Extension

If you come to a point in your graduate work where it becomes evident that you cannot complete your program within the time limit (seven years for Master of Science degree, five years for PhD candidates), you will need to request approval for a time extension from the Committee on Graduate Study. This requires that you submit 1) a completed petition 2) an unofficial graduate engineering transcript, and 3) a letter from you stating the reasons for the request, with your advisor or the Department's assigned Graduate Officer. Your letter, addressed to the Committee on Graduate Study, should also state the specific course of action you plan to take in order to complete your degree requirements, and the length of time needed for the extension. If the extension is approved, all materials are placed in your file for graduation clearance purposes.

D8 - Transfer Credit

The Graduate School of Engineering allows up to twelve (12) quarter hours of credit obtained from another institution to be used toward the Master of Science degree. To be eligible for transfer credits, the course(s) must be 1) in the student's field of study, 2) at the graduate level, 3) in an accredited (or if international, a recognized) college or university, and 4) carry grades of B or better. The credits cannot have been used toward any other degree and must have been taken within the time limit for your degree completion. Once entered in the program, a student wishing to take a course from another institution for transfer credit should petition for approval prior to pursuing the course.

If you are seeking transfer credit approval, you will need to complete a petition and provide an unofficial transcript of your graduate work at Northeastern, a course catalog description and an official transcript of the course you wish to transfer. Submit all of these materials to the Department Graduate Committee. If approved by the Department Graduate Committee, the material is sent to the Graduate School Office for final approval. The credits will be applied toward your degree requirements if all transfer credit criteria have been met. However, the grades do not carry over and are not included in the computation of your grade point average required for degree completion. Credits are granted as equivalent to required or elective courses in the Graduate School of Engineering.

University Facilities and Resources

The Boston Campus

The central Boston campus is built around a quadrangle, one side of which faces Huntington Avenue, a major artery dividing the campus. The buildings surrounding the quadrangle and the innovative design of new buildings such as the library and the Egan Research Center that have been added in recent years has maintained an architectural theme that is both attractive and functional.

The campus itself has been planned to provide easy access to classrooms, laboratories, and administrative offices through a series of connected walkways and a network of underground corridors providing routes that are especially convenient during periods of inclement weather. As the University continues to expand, recreational areas are integrated into the campus along with new academic facilities.

Suburban Facilities

Northeastern University's five suburban campuses provide administrative and classroom facilities for the University's graduate, adult and continuing education programs as well as the environment necessary for specific programs of study that could not be accommodated in an urban area.

The Warren Center provides a practical laboratory in outdoor education and conservation, and in camping administration, programming, and counseling. It also offers a summer campsite for various community and University groups and activities and is available as a conference and workshop site.

The Marine Science and Maritime Studies Center is located in Nahant, on Massachusetts Bay, 20 miles northeast of Boston and serves as a site for national and international as well as University research.

Henderson House is Northeastern University's conference center. Located 12 miles from Boston in suburban Weston, Henderson House hosts a variety of round-the-clock activities including residential seminars, workshops, short courses, and weekend meetings.

The Suburban Campus of Northeastern University is located in Burlington near the junction of Routes 128 and 3. Graduate courses in engineering and business administration, as well as undergraduate courses for part-time students are offered here. The Burlington Campus also offers special programs for adults and noncredit continuing education courses.

The Suburban Campus is situated close at hand to another Northeastern University facility, the Botanical Research Station in Woburn, which contains a small arboretum and a spacious greenhouse used for propagation and research.

The 20-acre Dedham Campus is located just off Route 128. This facility provides space for the College of Business Administration's High Technology MBA program and offices for the Center for Continuing Education, and houses the University's outdoor track and field facility.

The Henderson Boathouse

The Henderson boathouse is located on the banks of the scenic Charles River in Brighton, Massachusetts. The five-bay, two-story facility houses both the men's and women's crew teams.

University Libraries

Through their collections, services, staff, and facilities, the Northeastern University Libraries provide access to information integral to all academic and research activities. Librarians assist individuals and groups with bibliographic research strategies and with identifying, locating, evaluating, and using discipline-specific print, non-print, and electronic information resources. The Library offers a comprehensive instruction program, ranging from introductory sessions to advanced electronic database research geared to a particular topic or course. Students may also meet with a librarian to discuss specific or specialized research needs.

Snell Library, a large and comfortable, centralized library on the Boston campus, is open for research and study more than a hundred hours each week that classes are in session. A library at the Burlington campus supports the courses taught there. The collection at the Marine Science Center supports its research activities. Users of the Boston library can request the loan of materials from the Burlington collection, and vice versa.

The total holdings of the University Libraries include more than 875,000 volumes; 2,080,000 microforms; subscriptions to over 8,200 serials and newspapers; 170,000 government documents; and 19,000 audio, video, and computer software titles. The collections also include materials such as technical reports, music scores, maps, and CD-ROM databases; licensed Web resources are accessible through the Library's gateway on Nunet, the campus network. Web resources of particular interest to graduate engineering students are *Engineering Information (Ei) Village* (which includes *CompendexWeb*), the full text of the journals of the Institute of Physics and of the American Institute of Physics, and *MathSciNet*. Snell Library is also a selective depository for government publications, an archival depository for University publications, dissertations, and papers, and a repository for special collections.

Library services incorporate advanced technologies associated with information resources and networks, including an online catalog and circulation system, microcomputer and language laboratories, specialized equipment for users with disabilities, a media center with satellite program and remote audio and video transmission capability, a CD-ROM network, and connectivity to NUNET and the Internet. Students can access NULIS (Northeastern University Libraries Information System) from outside the Library via NUNET or through dial-in.

Many other library services are available to students, including a student peer tutoring program. There is an extensive language facility for students who wish to improve their speaking skills in English, or who wish to develop their skills in another language in preparation for working abroad. Students who wish to design and create quality visual presentation materials for class or for other talks, papers, and posters, may use the photographic, graphic, and computer facilities of the Media Production Laboratory. Visit the Library's home page at *http://www.neu.edu/library* for additional information about collections, services, and hours.

Other libraries and collections on the Boston campus include the African-American Institute Library, the Career Development and Placement Library, the Hillel House Collection, and the Law Library; these are administered separately from the University Libraries system.

Northeastern University is a member of the Boston Library Consortium, a cooperative arrangement among sixteen major academic and research institutions. Students may apply for a card that grants borrowing privileges at consortium libraries.

Computing Resource Center

The Division of Academic Computing provides student access to computing resources. A high speed intranet links users and facilities on the central campus and on three satellite campuses. The campus network is also connected via the internet to computing resources around the world. At the university, students have access to a network of UNIX workstations, microcomputer labs, and an array of specialized departmental computing equipment.

Graduate Student Housing

Housing in a University apartment facility is available on a first-come, first-served basis. These fully furnished apartment facilities offer units designed for two, three, or four students.

Department of Career Services

The Department of Career Services offers career counseling and job search assistance to all Northeastern students and alumni/ae. Career counseling helps our clients make decisions about a college major or career direction, develop plans for a career change, create effective job search strategies, or explore any other career related issue. Job search assistance is available through resume matching, a computerized system that matches the candidates resume with professional positions listed by employers. The On-campus Recruiting Program brings representatives from more than two hundred employer organizations to Northeastern to interview graduating students for full-time employment.

The Career Resource Center houses a collection of career literature, including occupational information, resume and interviewing resources, job search guides and directories of employers. The Center maintains a job bank of current local, national, and international job opportunities and internships. Employer files contain annual reports, product information and descriptions of training programs. Daily walk-in hours allow students and alumni/ae to seek convenient assistance with resumes, job search correspondence or any other career related question.

Sport, Dance and Exercise Facilities

Through its Cabot Gymnasium and the Marino Center for Physical Education, Dockser Hall and Barletta Natatorium, Northeastern University offers a wide variety of specialized facilities, including basketball courts, dance studio, indoor athletic field and running track, gymnastics room, combatives room, weight-training rooms, swimming pool, crew practice tank, racquetball courts, and motor performance and exercise physiology laboratories. The Matthews Arena, with seating for more than 5,000 fans, provides home ice to the University's varsity and subvarsity hockey teams and, when the portable playing floor is down on the ice, home court to the University's basketball teams.

For organized athletics requiring facilities not available on the main campus, Northeastern maintains several off-campus locations, including the Henderson Boat House, in Brighton. The Edward S. Parsons Field, on Kent Street in Brookline, is the playing ground for the football, baseball, women's lacrosse and women's field hockey teams, tennis, and some intramurals.

The Bernard and Jolane Solomon Track

The Bernard M. and Jolane Solomon Track, an outdoor track and field facility in Dedham, has an eight lane, Action Track 200 running surface, and an expansive area for con-current jumping and field events. This facility hosts dual and championship meet competition, and is a permanent site for Northeastern University track athletics.

Curry Student Center

The Curry Student Center is home to Northeastern's 185 Student Organizations, Student Government Offices, Information Center, Copy Center, The Print Media (The Northeastern News, Yearbook, Etc.), and WRBB Radio Station. In addition, the Center houses a computer lab, typing area, meeting rooms, student lounge, The Commuter Referral Office, and the Ballroom, which serves many social and academic functions.

The Curry Center is supported by student fees and strives to offer a comfortable atmosphere for commuter and resident students alike. It is also used by the Northeastern Community for the many social, recreational, academic and cultural activities held on campus.

Lane Health Center

A comprehensive program of medical care is provided to all full-time graduate and undergraduate students. The University maintains a Health Services Clinic equipped to deal promptly with any medical condition that may arise. All entering full-time students must submit a pre-entrance physical examination form provided by the Lane Health Center prior to registration. Failure to fulfill this requirement can delay registration and result in a penalty fee and additional fee for a physical examination.

Counseling and Testing Center

The Counseling Center provides a broad range of counseling services for Northeastern students. These services include assistance in resolving personal loss and life adjustment problems, developing satisfying interpersonal relationships, choosing an appropriate college major, career planning, improving study skills, and dealing with difficult feelings such as excessive anxiety or depression. The center provides short-term counseling (twelve sessions maximum). Assistance is offered in the form of referrals and resources if longer term treatment is needed.

In addition to individual counseling, students may take psychological tests to increase their knowledge of themselves, join a group of students with whom they share concerns, and use self-help tapes. There is no charge for these services for enrolled NU students.

Disability Resource Center

The Disability Resource Center's (DRC) mission is to ensure that students with disabilities have equal access to higher education via support services and advocacy. DRC provides support services on an individual basis. The Center's services include, but are not limited to: readers and scribes, sign-language interpreters and translators, note-taking, disability-related academic advice, liaison and advocacy services for students, faculty, staff, and administrators, counseling and referral services, campus orientation, accessible accommodations, support groups and HP parking.

Support services are available for, but not limited to, the following: students with learning disabilities, students who are head injured, students who are deaf or hard of hearing (HH), students who are blind or have visual impairment, students with degenerative or chronic conditions, and students with mental disorders.

Network Northeastern

Network Northeastern uses the microwave-based Instructional Television Fixed Service (ITFS) system to broadcast courses to subscriber companies and to the Burlington and Dedham campuses. The network telecasts live classroom instruction from the Boston campus to remote sites where

students interact with instructors via a telephone-based talkback system. Class materials are delivered via courier service, U.S. Mail, facsimile, or electronic mail.

Network Northeastern currently broadcasts graduate courses in electrical engineering, mechanical, industrial and manufacturing engineering and information systems to over thirty local corporations. Network Northeastern also delivers graduate level and short courses to corporations throughout the U.S. via satellite. Further information may be obtained from Network Northeastern at 328 Columbus Place, Boston, Massachusetts, 02115, by viewing our website: www.neu.edu/network-nu, or by calling (617) 373-5620.

English Language Center

The English Language Center (ELC) provides an important resource for students at Northeastern who speak English as a second language. Its goal is to ensure that these students are proficient enough to carry full-time studies in a degree program without language-related problems. The ELC provides testing for students whose acceptance in degree programs is "conditional upon [their] taking the English language Center ESL Exam" and offers non-credit ESL courses at five levels in the Intensive English Program to help students achieve the language proficiency they require.

In addition to serving students, the English Language Center Provides advice and consultation to the Northeastern community at large. Center staff are available to answer questions from teachers, administrators, and students, and are able to design special programs for special needs on short notice.

International Student Office (ISO)

The International Student Office (ISO) coordinates an array of services and programs for approximately 2,500 international students, scholars, and faculty from more than 130 countries. Services to the international community range from advising and interpreting immigration regulations and federal laws, to organizing more than seven weeks of orientation programming throughout the year. The ISO also assists with international admissions, currency exchanges, cultural adjustment issues, visiting faculty appointments, a student mentor program, sponsored international student concerns, and numerous matters that pertain to both undergraduate and graduate international students as well as to the inter-culturally minded community.

The ISO strives to foster an appreciation of all cultures and to facilitate cross-cultural understanding, especially between American and international students. To achieve this aim, ISO staff work closely with student organizations, University departments, and community institutions. Among the inter-culturally focused activities of the ISO are: a hospitality program linking international students with families in the US, an international art series, an international spouse program, a two-month cultural festival entitled *International Carnevale*, and regional excursions as part of its "ISO on the Go" series. Visit the International Student Office, Northeastern University, 203 Ell Hall, Boston, Massachusetts, 02115 for further information or call the ISO at (617) 373-2318.

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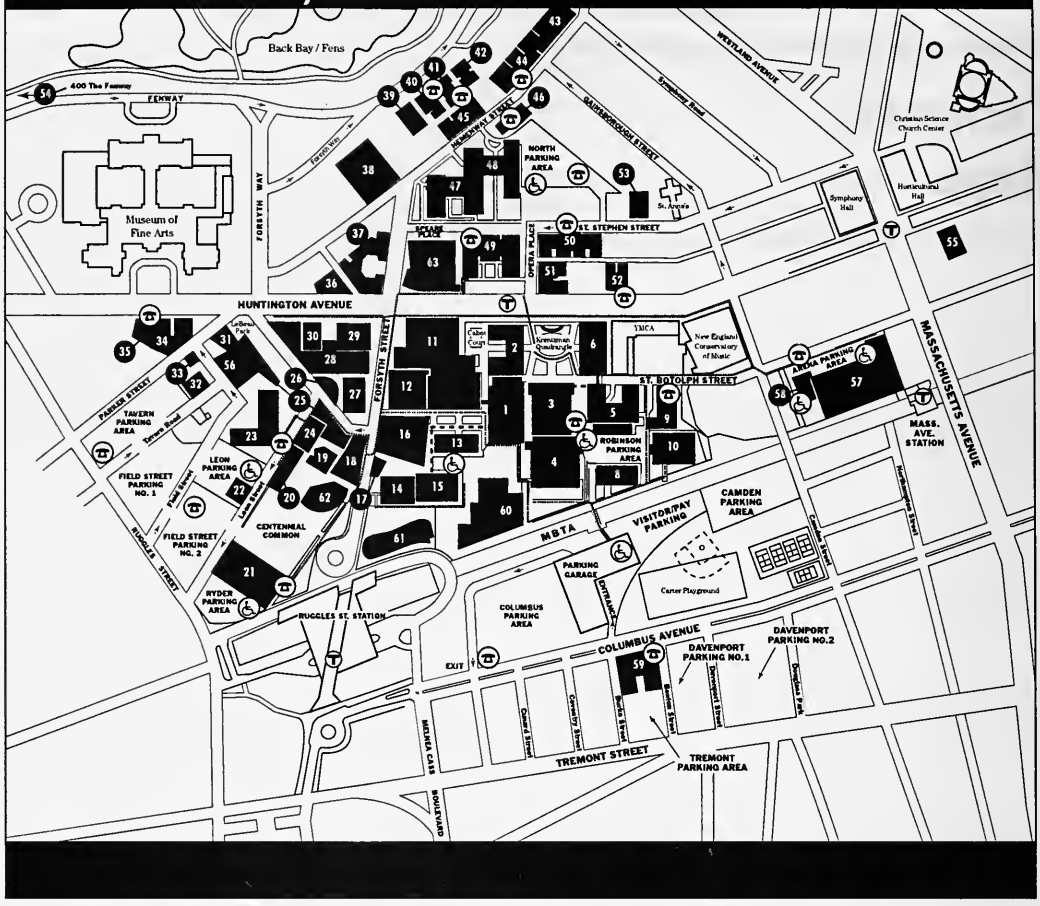


Academic and Service Buildings

- 22 John D. O'Bryant African-American Institute (AF)
- 12 Barletta Natatorium (BN)
- 19 Boiler Plant
- 11 Cabot Physical Education Building (CB) TTY: Rm 110
- 39 Cahners Hall (CA) TTY: Rm 151
- 28 Cargill Hall (CG)
- 13 Churchill Hall (CH)
- 62 Classroom Building (CL)
- 59 Columbus Place (716 Columbus Avenue) (CP)
- 9 Cullinane Hall (CN)
- 4 John A. and Marcia E. Curry Student Center (Student Lounge) (SC) TTY: Rm 255
- 40 Cushing Hall (CU)
- 14 Dana Research Center (DA)
- 27 Dockser Hall (DK) TTY: Rm 107
- Dodge Hall (DG)
- 61 Maureen and Richard J. Egan Engineering/Science Research Center
- 3 Ell Student Building (Auditorium) (EL) TTY: Rms 04,104
- 56 Field Street (FS)
- 16 Forsyth Building (FR) TTY: Rms 100, 135
- 17 Forsyth Building Annex (FA)
- 38 Forsyth Dental Building (FE)
- 1 Hayden Hall (HA) TTY: Rms 120, 202
- 33 Hillel-Frager (HF)
- 24 Holmes Hall (HO) TTY: Rm 276
- 55 236 Huntington Avenue (HU)
- 10 Hurtig Hall (HT)
- 26 Kariotis Hall (KA)
- 41 Kerr Hall (Faculty Center) (KH)
- 29 Knowles Center (KN)
- 25 Lake Hall (LA) TTY: Rm 203
- 63 Roger M. and Michelle S. Marino Recreation Center
- 57 Matthews Arena (MA)
- 58 Matthews Arena Annex (MX)
- 20 Meserve Hall (ME) TTY: Rm 305
- 5 Mugar Life Science Building (Peabody Health Professions Center) (MU)
- 18 Nightingale Hall (NI) TTY: Rm 125
- 31 Parker Building (PA)
- 2 Richards Hall (RI) TTY: Rms 150, 254
- 8 Robinson Hall (RB)
- 21 Ryder Hall (RY) TTY: Rms 170, 180, 251, 270
- 15 Snell Engineering Center (SN) TTY: Rm 120
- 60 Snell Library (SL) TTY: Reference Desk
- 50 122 St. Stephen Street (SS)
- 30 Stearns Center (ST) TTY: Rm 302
- 32 26 Tavern Road (TA)

Residence Buildings

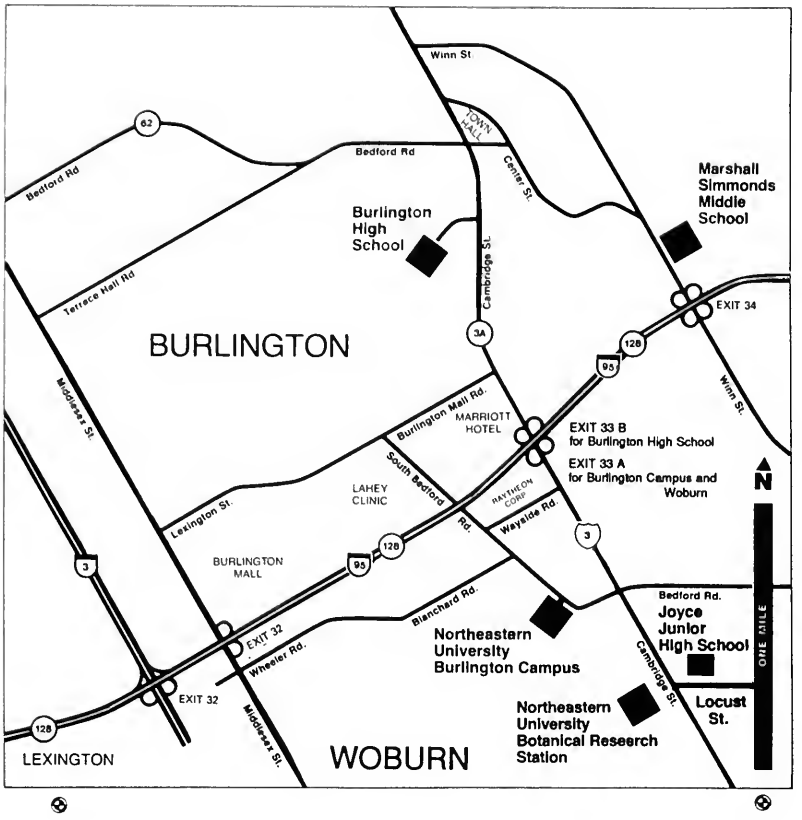
- 34 Burstein Hall
- 43 Kennedy Hall
- 46 142–148 Hemenway Street
- 45 153 Hemenway Street and Loftman Hall
- 7 316 Huntington Avenue (Northeastern at the YMCA)
- 52 319 Huntington Avenue
- 51 337 Huntington Avenue
- 36 407 Huntington Avenue
- 41 Kerr Hall
- 53 Light Hall
- 45 Loftman Hall and 153 Hemenway Street
- 42 Melvin Hall
- 35 Rubenstein Hall
- 44 Smith Hall
- 49 Speare Hall
- 48 Stetson East TTY (public)
- 47 Stetson West
- 50 106/110/116/122 St. Stephen Street
- 23 Willis Hall
- 37 White Hall
- 54 400 The Fenway

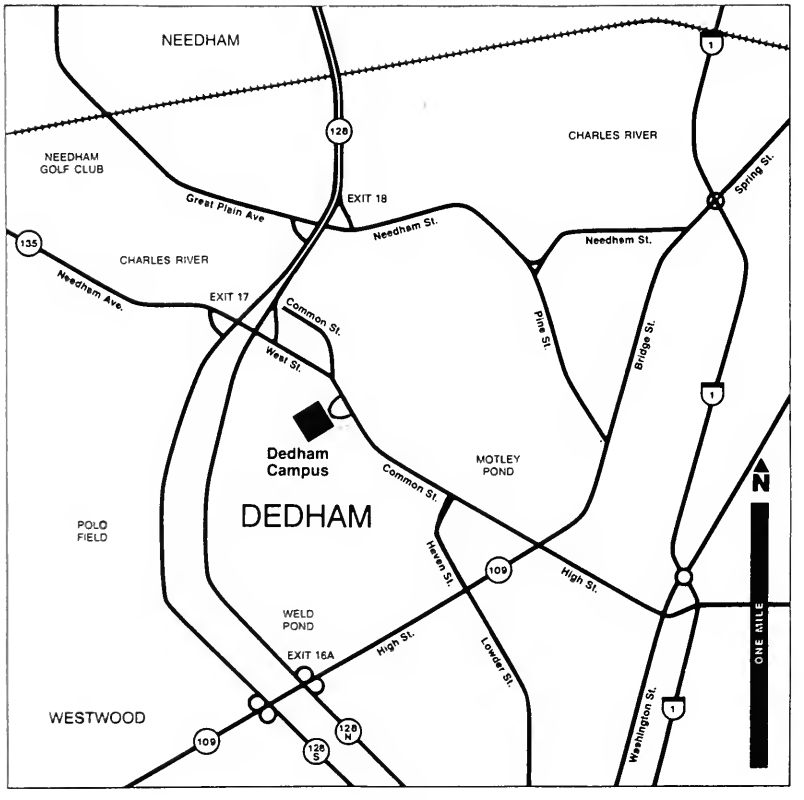
Key

- Academic, residential, and service buildings
- Handicap parking
- Accessible routes
- Parking areas
- Street direction
- Underground tunnel
- Emergency telephone
- TTY locations — TTY: Rm 000

See alphabetic list of buildings for TTY locations.

Maps are provided by the Information Center, 115 Richards Hall, extension 2736 (TTY extension 3768). Some buildings on this map are used but not owned by Northeastern University. 5/96


Winn St.
TOWN HALL
62
Bedford Rd
Bedford Rd
Center St.
Marshall Simmonds Middle School
Burlington High School
Terrace Hall Rd
Cambridge St.
3A
EXIT 34
128
95
BURLINGTON
Middlesex St.
Burlington Mall Rd.
MARRIOTT HOTEL
EXIT 33 B for Burlington High School
EXIT 33 A for Burlington Campus and Woburn
Winn St.
South Bedford Rd.
LAHEY CLINIC
RAYTHEON CORP.
Wayside Rd.
Lexington St.
3
BURLINGTON MALL
128
95
Bedford Rd.
Joyce Junior High School
Blanchard Rd.
EXIT 32
Wheeler Rd.
Northeastern University Burlington Campus
Cambridge St.
ONE MILE
EXIT 32
Locust St.
128
Middlesex St.
LEXINGTON
WOBURN
Northeastern University Botanical Research Station
N


NEEDHAM
1
128
CHARLES RIVER
NEEDHAM GOLF CLUB
Great Plain Ave
EXIT 18
Needham St.
Spring St.
Needham St.
135
CHARLES RIVER
Needham Ave.
EXIT 17
Common St.
Pine St.
Bridge St.
West St.
1
Dedham Campus
MOTLEY POND
Common St.
DEDHAM
N
POLO FIELD
Haven St.
109
High St.
WELD POND
High St.
EXIT 16A
Lowder St.
ONE MILE
Washington St.
WESTWOOD
109
128 N
128 S
1

Additional Information About Northeastern University

The Northeastern University Graduate School of Engineering Student Guide and Catalogue contains the University's primary statements about graduate engineering academic programs and degree requirements, as authorized by the president or Board of Trustees. For information about other academic policies and procedures, student responsibilities, academic and cocurricular life, faculty rights and responsibilities, or general personnel policies, benefits, and services, please refer to the *Academic Operations Manual, Undergraduate and Graduate Student Handbook, Cooperative Education Handbook, Benefits and Services Handbook*, and related procedural guides, as appropriate.

Accreditation Statement

Northeastern University is accredited by the New England Association of Schools and Colleges, Inc., which accredits schools and colleges in the six New England states. Accreditation by the Association indicates that the institution has been carefully evaluated and found to meet standards agreed upon by qualified educators.

Delivery of Services

Northeastern University assumes no liability for delay or failure to provide educational or other services or facilities due to causes beyond its reasonable control. Causes include, without limitation, power failure, fire, strikes by University employees or others, damage by natural elements, and acts of public authorities. The University will, however, exert reasonable efforts, when it judges them to be appropriate, to provide comparable service, facilities, or performance; but its inability or failure to do so shall not subject the University to liability.

Emergency Closing of the University

Northeastern University has made arrangements to notify students, faculty, and staff by radio and television when it becomes necessary to cancel classes because of extremely inclement weather. AM stations WBZ (1030), WRKO (680), and WILD (1090), and FM station WBUR (90.9) are the radio stations authorized to announce the University's decision to close. Television stations WBZ-TV4, WCVB-TV5, and WHDH-TV7 also report cancellations. Since instructional television courses originate from live or broadcast facilities at the University, neither the classes nor the courier service operate when the University is closed. Please listen to the radio or television to determine whether the University will be closed. If a storm occurs at night, the announcement of University closing is given to the radio stations at approximately 6 AM. Classes are generally canceled for that entire day and evening at all campus locations unless stated otherwise. When a storm begins late in the day, cancellations of evening classes may be announced. This announcement is usually made between 2-3 PM.

Equal Opportunity Policy

Northeastern University does not discriminate on the basis of race, color, religion, sex, sexual orientation, age, national origin, disability, or veteran status in admission to, access to, treatment in, or employment in its programs and activities. In addition, Northeastern University will not condone any form of sexual harassment. Handbooks containing the University's nondiscrimination policies and its grievance procedures are available in the Office of Affirmative Action, 175 Richards Hall. Inquiries regarding the University's nondiscrimination policies may be directed to:

Donnie Perkins, Dean/Director
Office of Affirmative Action
424 Columbus Place
Northeastern University
Boston, Massachusetts 02115
(617) 373-2133

Inquiries concerning the application of nondiscrimination policies may also be referred to the Regional Director, Office for Civil Rights, United States Department of Education, J.W. McCormack Building, Post Office Court House, Room 222, Boston, Massachusetts 02109-4557.

Family Educational Rights and Privacy Act

In accordance with the Family Educational Rights and Privacy Act of 1974, Northeastern University permits its students to inspect their records wherever appropriate and to challenge specific parts of them when they feel it is necessary to do so. Specific details of the law as it applies to the University are printed in the *Undergraduate and Graduate Student Handbook* and are distributed annually at registration for the University's colleges and graduate schools.

Insufficient Enrollment Disclaimer

Northeastern University reserves the right to cancel any course if minimum enrollments, appropriate faculty, or academic facilities are unavailable to meet standards.

Tuition and Fee Policy

Tuition rates, all fees, rules and regulations, and courses and course content are subject to revision by the President and the Board of Trustees at any time.

Northeastern University
Graduate School of Engineering
130 Snell Engineering Center
Boston, MA 02115